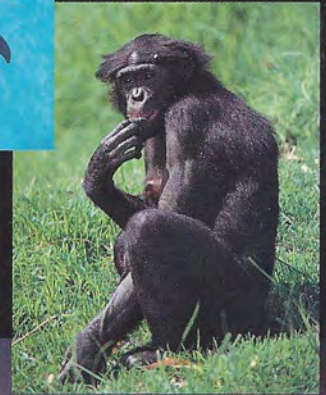


The PLANETARY REPORT

Volume XVI

Number 3

May/June 1996



SETI: Is Intelligence Commonplace?

On the Cover:

The Search for Extraterrestrial Intelligence is based on the assumption that intelligence of a technological sort has arisen on more than one planet in our galaxy. On Earth, some forms of life exhibit intelligence; others do not. Ravens have been seen making and using tools; mushrooms and algae have not. Dolphins, like humans, have evolved a complex language, and bonobos display many behaviors remarkably similar to human activities. But of all the life-forms that have come and gone on Earth, only one has built radio telescopes to listen for signals from other life-forms. The likelihood of a similar life-form existing on another planet is a topic for lively debate.

Photos: Clockwise from left: Diana L. Stratton, David M. Dennis, Randy Morse, Mike Bacon and Roy Toff (all Tom Stack & Associates). Bottom: Seth Shostak

From The Editor

When, you might ask, is *The Planetary Report* planning to cover the results of the *Galileo* probe mission? After all, the probe plunged into Jupiter's atmosphere last December. The simple answer is this: when the results are ready. But that might not be so simple to understand, and it has to do with the way most media report on planetary missions.

Typically, reporters cover exciting events, like spacecraft flybys and probe plunges, and lose interest in the painstaking data analysis that provides the real value from planetary exploration. At press conferences, they pepper the scientists with questions, demanding to know What It All Means. They don't hear the cautions against putting too much stock in instant science. Then, when scientists change their minds, no one hears the new, truer story.

That is what we hope to present here. Scientists are even now revising their analyses of *Galileo* results. These analyses are different from those initially reported in the popular press. You'll soon see the revised picture of Jupiter in our pages. We hope you'll find this more valuable than reports rushed into print too soon.

—Charlene M. Anderson

Table of Contents

Volume XVI

Number 3

May/June 1996

Features

4 The Search for Extraterrestrial Intelligence: Scientific Quest or Hopeful Folly? A Debate Between Ernst Mayr and Carl Sagan

Does extraterrestrial intelligence exist? It's a question that provokes vociferous debate and regularly generates headlines in supermarket tabloids. It's also a question that science can address, and two distinguished practitioners present opposing sides of the debate.

14 New Eyes for Mars: Testing Cameras for the Mars '96 Mission

Have you ever wondered how an earthly landscape might look through a spacecraft's eyes? The cameras for the *Mars '96* spacecraft have been tested, giving us the opportunity to preview the system that will soon be showing us the landscape of the Red Planet.

16 Fly to Saturn With Cassini: Society Members Invited Along

At The Planetary Society, we try to provide our members with every possible opportunity to participate in missions to other worlds. In this case, we are helping the Jet Propulsion Laboratory, as well as giving you the chance to fly to Saturn.

Departments

3 Members' Dialogue

We recently received a letter from a New Millennium Committee member that genuinely touched the staff at headquarters; we share it here with all Society members. Plus, we discuss credit where credit is due, Society Advisor Barney Oliver and defense cutbacks.

17 World Watch

The Russian-led *Mars '96* mission is being prepared for launch, as are NASA's *Mars Pathfinder* and *Global Surveyor*. A Russian experiment, with the Society-supported Mars Microphone, will fly on the Mars Surveyor lander. And NASA's budget problems continue.

18 News and Reviews

Our faithful columnist covers two newsworthy objects: Comet Hyakutake has reminded people that our solar system is a dynamic and exciting place. But Pluto, poor Pluto—it's yet to be visited by a spacecraft and people are already trying to downgrade it from planet status.

19 Society News

Here are more opportunities to get involved with Society events and activities.

20 Questions and Answers

We bring you a special edition of this column, devoted entirely to telling time.

Editor's Note:

Basics of Spaceflight is on a brief hiatus. It will return in our July/August issue.

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Members' Dialogue

Responsibilities

Thank you for the invitation to join the New Millennium Committee. My acceptance form is enclosed. I agonized for two days over this decision. This is a significant expenditure for me, and I wrote out a long list of other uses, some personally urgent, for the money. I will be married in May. My fiancée and I are selling a house under distress circumstances. Two teenage girls have to be educated in an increasingly competitive workplace. I could go on.

Then a realization struck me. Nations of the world find themselves allocating scarce resources and making tough choices. As an individual, I am in a similarly underfunded and leaky boat. I can make personal decisions for myself. The Society, however, represents my best hope for influencing governments.

Few opportunities arise within a lifetime for individuals to make a culturally significant difference. Equally important, I am convinced that our sense of personal self-worth never rises higher than when we reach up outside of our own self-centered considerations and "do the right thing." Lofty potentials of the human race will never be fulfilled if we remain confined at the bottom of Earth's constraining gravity well. Considering a few of the disturbing realities of human pressure upon our fragile biosphere, it is not clear that we will be better able in the future to undertake the collective challenge of space exploration. Nevertheless, we progress or we stagnate and wither.

By supporting The Planetary Society and its goals, I move away from hopelessness and despair. I shoulder a portion of my responsibility as a citizen of the world and a steward of my species. Finally, and most privately rewarding, when I look in the mirror, a person much more to my liking smiles back at me.

—KENT H. FAIRFIELD,
Hayward, California

Editor's note: New Millennium Committee membership is open to those who contribute \$500.00 or more to the Society each year.

Barney Oliver

I learned with great sadness (from my January/February 1996 issue of *The Planetary Report*) of Barney Oliver's death. Barney was a personal friend whose opinions I have always held in the highest regard. When I saw him last June, he was still working on the Search for Extraterrestrial Intelligence at his office in Mountain View. At that time, he expressed great sadness and profound disappointment as he recognized that he would not see SETI succeed during his lifetime. Although Barney's body was weak and required more and more of his immediate attention, his spirit was still on full alert.

I grieve not only for myself, but for all space-minded people, and especially for my fellow SETI followers, at the loss of our strongest advocate and ally. My heart goes out to all of those close to Barney.

—JOE WEBB, *West Melton, Christchurch, New Zealand*

Defense Dollars

In response to A.P. Vinayagam's letter on NASA's budget (see the January/February 1996 issue of *The Planetary Report*), I must say that although the intentions are good, the effect on NASA's capabilities could be profoundly negative. The end of the Cold War has led many people to believe that the "peace dividend" expected as a result of a large defense drawdown could reinvigorate NASA. I believe that such a large drawdown would adversely affect the federally funded research and development efforts that directly or indirectly support NASA's programs.

It is not widely known that Sandia National Laboratories, a Department of Energy facility that is significantly funded by defense

dollars, has been a major contributor to NASA's programs. When it was discovered that the region around Jupiter presented radiation hazards to electronic instruments, NASA relied on Sandia's expertise in radiation-hardened electronics (originally developed for nuclear weapons) to produce *Galileo's* computer chips. When NASA engineers needed parachute and air-bag design for Mars *Pathfinder*, they came to Sandia for its expertise, again developed originally to support the nuclear weapons program.

I also believe that convincing Congress of anything hinges on the issue's direct effect on reelection potential and voter support. The Planetary Society must find a way to make the case to voters that space equals jobs. Once voters begin to clamor for federally funded space projects, members of Congress will respond or risk losing their seats in Washington.

—PAUL KLARER,
Albuquerque, New Mexico

Proper Credit

Your March/April 1996 issue is excellent, as always. I really enjoy being a member of an organization that takes such a positive stance and also follows through to actually accomplish things that forward the goals of the group. Bravo!

However, there is an item that should be mentioned concerning the credit for the wonderful cover photo of Andromeda. Before they were married, photo credits always went to Tony Hallas and Daphne Mount when their terrific astrophotographs were published. Now that it's Mr. and Mrs. Hallas, she has received no recognition for her part of this astonishingly great work.

—JIM BRICKEN,
Felton, California

Please send your letters to Members' Dialogue, The Planetary Society, 65 North Catalina Ave., Pasadena, CA 91106-2301 or e-mail tps.des@genie.geis.com.

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THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

Scientific Quest or

A DEBATE BETWEEN ERNST MAYR AND CARL SAGAN

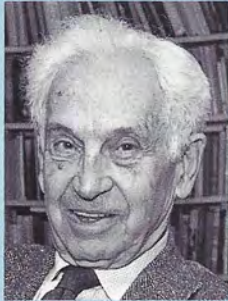


Photo: Jane Reed/Harvard News Office

Ernst Mayr—“Darwin’s current bulldog” is how *Scientific American* describes Ernst Mayr, recalling Thomas Huxley, the 19th-century scientist who is remembered largely because of his vociferous defense of the theory of evolution. Mayr will be remembered for championing evolution as well as for his many achievements in the field of biology. In systematics, ornithology, evolutionary biology and the history of science, he stands as a giant of the 20th century. He has been awarded the National Medal of Science, the Balzan Prize for his contributions to evolutionary biology and the Sarton Medal for his work in the history of science. As the Alexander Agassiz Professor of Zoology, Emeritus, of Harvard University, the 91-year-old Mayr still works every day, tackling challenging subjects, such as the Search for Extraterrestrial Intelligence.

Since humans first looked up, they have seen in the skies the phantoms of their wondering minds. If there is one thread that links the ancient Greek philosophers to modern space scientists, it is the uncertainty about the plurality of worlds. Vast and ancient beyond ordinary human understanding, the universe leaves us pondering the ultimate significance, if any, of our tiny but exquisite life-bearing blue planet.

With the development of technology and our present understanding of the laws of nature, the human species is now in a position where the possibility of extraterrestrial civilizations can be verified by experiment. But because we have yet to find a single piece of concrete evidence of alien intelligence, a philosophical battle has arisen between those who might be called contact optimists—who generally embrace SETI—and the proponents of the uniqueness hypothesis, which suggests that Earth is the only technical civilization in our galaxy.

In these pages, we present both sides of this philosophical and scientific battle. Which view is more palatable to you? Read on and decide for yourself. —**Guillermo A. Lemarchand**

This debate between two of the most prominent scientists of the 20th century first appeared in *The Bioastronomy News*, a special-interest newsletter published by The Planetary Society. The debate was conceived by newsletter editor Guillermo A. Lemarchand, a researcher at the Argentine Institute of Radio Astronomy and a leader in the Society’s META II project.

THE IMPROBABILITY OF SUCCESS

by *Ernst Mayr*

What is the chance of success in the Search for Extraterrestrial Intelligence? The answer to this question depends on a series of probabilities. I have attempted to make a detailed analysis of this problem in a German publication (Mayr, 1992) and shall attempt here to present in English the essential findings of this investigation. My methodology consists in asking a series of questions that narrow down the probability of success.

How Probable Is It That Life Exists Somewhere Else in the Universe?

Even most skeptics of the SETI project will answer this question optimistically. Molecules that are necessary for the origin of life, such as amino acids and nucleic acids, have been identified in cosmic dust, together with other macromolecules, and so it would seem quite conceivable that life could originate elsewhere in the universe.

Some of the modern scenarios of the origin of life start out with even simpler molecules—a beginning that makes an independent origin of life even more probable. Such an independent origin of life, however, would presumably result in living entities that are drastically different from life on Earth.

RESTRIAL INTELLIGENCE: Hopeful Folly?



Photo: Andy Levin/Parade

Carl Sagan – Carl Sagan is the David Duncan Professor of Astronomy and Space Science and Director of the Laboratory for Planetary Studies at Cornell University; Distinguished Visiting Scientist at the Jet Propulsion Laboratory of the California Institute of Technology; and cofounder and President of The Planetary Society. He is one of the few astronomers with a background in biology: research assistant to Nobel laureate geneticist H.J. Muller at Indiana University, Visiting Assistant Professor of Genetics at the Stanford University Medical School and author of the article “Life” in the *Encyclopaedia Britannica*. He is coauthor, with I.S. Shklovskii, of the classic SETI text, *Intelligent Life in the Universe*, and has made many research contributions to the study of the prebiological organic chemistry on Earth and in the outer solar system and of the origin of life.

Where Can One Expect to Find Such Life?

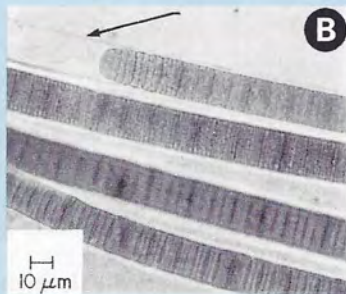
Obviously, only on planets. Even though we have up to now secure knowledge only of the nine planets of our solar system, there is no reason to doubt that in all galaxies there must be millions if not billions of planets. The exact figure, for instance, for our own galaxy can only be guessed.

How Many of These Planets Would Have Been Suitable for the Origin of Life?

There are evidently rather narrow constraints for the possibility of the origin and maintenance of life on a planet.

There has to be a favorable average temperature; the seasonal variation should not be too extreme; the planet must have a suitable distance from its sun; it must have the appropriate mass so that its gravity can hold an atmosphere; this atmosphere must have the right chemical composition to support early life; it must have the necessary consistency to protect the new life against ultraviolet and other harmful radiations; and there must be water on such a planet. In other words, all environmental conditions must be suitable for the origin and maintenance of life.

One of the nine planets of our solar system had the right



Perhaps as early as 3.8 billion years ago, life appeared on Earth. The earliest fossils are of prokaryotic (“before a nucleus”) organisms, such as cyanobacteria, also called blue-green algae. To the left (A) is an example of one of the filamentous forms, dated at 3.465 billion years old, with an interpretive drawing beneath. Such organisms were stupendously successful and, in fact, dominated Earth for the first 2 to 3 billion years that life existed. The forms of cyanobacteria have remained remarkably constant. (B) above is a living form, while (C) is the fossil of a similar organism about 950 million years old.

Photos: J. William Schopf

kind of mixture of these factors. This, surely, was a matter of chance. What fraction of planets in other solar systems will have an equally suitable combination of environmental factors? Would it be one in 10, or one in 100, or one in 1,000,000? Which figure you choose depends on your optimism. It is always difficult to extrapolate from a single instance. This figure, however, is of some importance when you are dealing with the limited number of planets that can be reached by any of the SETI projects.

What Percentage of Planets on Which Life Has Originated Will Produce Intelligent Life?

Physicists, on the whole, will give a different answer to this question than biologists. Physicists still tend to think more

Conditions According to Mayr That Must Be Met for the Success of SETI

Condition	Likelihood
1 Extraterrestrial life must be able to originate repeatedly.	Probable
2 Other habitable planets similar to Earth must be available.	Probable
3 The planet must have conditions that enable the development of intelligent life.	Improbable
4 Extraterrestrial life must adapt "toward" high intelligence.	Highly improbable
5 The extraterrestrial life-forms must grow intelligent enough to found a civilization.	Improbable
6 The extraterrestrial civilization must be able to send and receive signals.	Improbable
7 The life-forms' sense organs must be adapted to receive electronic signals.	Improbable
8 The civilization must be long-lived and sending signals for a long time.	Improbable

deterministically than biologists. They tend to say that if life has originated somewhere, it will also develop intelligence in due time. The biologist, on the other hand, is impressed by the improbability of such a development.

Life originated on Earth about 3.8 billion years ago, but high intelligence did not develop until about half a million years ago. If Earth had been temporarily cooled down or heated up too much during these 3.8 billion years, intelligence would have never originated.

When answering this question, one must be aware of the fact that evolution never moves in a straight line toward an objective ("intelligence"), as happens during a chemical process or as a result of a law of physics. Evolutionary pathways are highly complex and resemble more a tree with all of its branches and twigs.

After the origin of life—that is, 3.8 billion years ago—life on Earth consisted for 2 billion years only of simple prokaryotes, cells without an organized nucleus. These bacteria and their relatives developed surely 50 to 100 different (some perhaps very different) lineages, but, in this enormously long time, none of them led to intelligence. Owing to an astonishing, unique event that is even today only partially explained, about 1,800 million years ago the first eukaryote originated, a creature with a well-organized nucleus and the other characteristics of "higher" organisms. From the rich world of the protists (consisting of only a single cell), there eventually originated three groups of multicellular organisms: fungi, plants and animals. But none of the millions of species of fungi and plants was able to produce intelligence.

The animals (Metazoa) branched out in the Precambrian and Cambrian time periods to about 60 to 80 lineages (phyla). Only a single one of them, that of the chordates, led eventually to genuine intelligence. The chordates are an old and well-diversified group, but only one of its numerous lineages, that of the vertebrates, eventually produced intelligence. Among the vertebrates, a whole series of groups evolved—types of fishes, amphibians, reptiles, birds and mammals. Again, only a single lineage, that of the mammals, led to high intelligence. The mammals had a long evolutionary history which began in the Triassic Period, more than 200 million years ago, but only in the latter part of the Tertiary Period—that is, some 15 to 20 million years ago—did higher intelligence originate in one of the circa 24 orders of mammals.

The elaboration of the brain of the hominids began less than 3 million years ago, and that of the cortex of *Homo sapiens* occurred only about 300,000 years ago. Nothing demonstrates the improbability of the origin of high intelligence better than the millions of phyletic lineages that failed to achieve it.

How many species have existed since the origin of life? This figure is as much a matter of speculation as the number of planets in our galaxy. But if there are 30 million living species, and if the average life expectancy of a species is about 100,000 years, then one can postulate that there have been billions, perhaps as many as 50 billion species since the origin of life. Only one of these achieved the kind of intelligence needed to establish a civilization.

To provide exact figures is difficult because the range of variation both in the origination of species and in their life expectancy is so enormous. The widespread, populous species of long geological duration (millions of years), usually encountered by the paleontologist, are probably exceptional rather than typical.

Why Is High Intelligence So Rare?

Adaptations that are favored by selection, such as eyes or bioluminescence, originate in evolution scores of times independently. High intelligence has originated only once, in human beings. I can think of only two possible reasons for this rarity. One is that high intelligence is not at all favored by natural selection, contrary to what we would expect. In fact, all the other kinds of living organisms, millions of species, get along fine without high intelligence.

The other possible reason for the rarity of intelligence is that it is extraordinarily difficult to acquire. Some grade of intelligence is found only among warm-blooded animals (birds and mammals), not surprisingly so because brains have extremely high energy requirements. But it is still a very big step from "some intelligence" to "high intelligence."

The hominid lineage separated from the chimpanzee lineage about 5 million years ago, but the big brain of modern man was acquired less than 300,000 years ago. As one scientist has suggested (Stanley, 1992), it required complete emancipation from arboreal life to make the arms of the mothers available to carry the helpless babies during the final stages of brain growth. Thus, a large brain, permitting high intelligence, developed in less than the last 6 percent of the life on the hominid line. It seems that it requires a complex combination of rare, favorable circumstances to produce high intelligence (Mayr, 1994).

How Much Intelligence Is Necessary to Produce a Civilization?

As stated, rudiments of intelligence are found already among birds (ravens, parrots) and among non-hominid mammals (carnivores, porpoises, monkeys, apes and so forth), but none of these instances of intelligence has been sufficient to found a civilization.

Is Every Civilization Able to Send Signals Into Space and to Receive Them?

The answer quite clearly is no. In the last 10,000 years, there have been at least 20 civilizations on Earth, from the Indus, the Sumerian and other Near Eastern civilizations, to Egypt, Greece and the whole series of European civilizations, to the Mayas, Aztecs and Incas, and to the various Chinese and Indian civilizations. Only one of these reached a level of technology that has enabled it to send signals into space and to receive them.

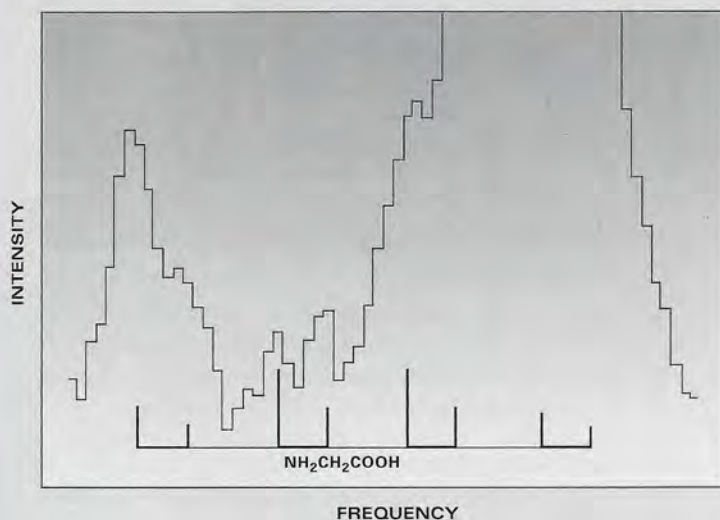
Would the Sense Organs of Extraterrestrial Beings Be Adapted to Receive Our Electronic Signals?

This is by no means certain. Even on Earth, many groups of animals are specialized for olfactory or other chemical stimuli and would not react to electronic signals. Neither plants nor fungi are able to receive electronic signals. Even if there were higher organisms on some planet, it would be rather improbable that they would have developed the same sense organs that we have.

How Long Is a Civilization Able to Receive Signals?

All civilizations have only a short duration. I will try to emphasize the importance of this point by telling a little fable.

Let us assume that there were really intelligent beings on another planet in our galaxy. A billion years ago, their astronomers discovered Earth and reached the conclusion that this planet might have the proper conditions to produce intelligence. To test this, they sent signals to Earth for a billion years without ever getting an answer. Finally, in the year 1800 (of our calendar) they decided they would send signals only for another 100 years. By the year 1900, no answer had been received, so they concluded that surely



The building blocks of life may even be found in interstellar space. This spectrum of a molecular cloud near our galactic center shows peaks at some of the frequencies expected for the glycine molecule ($\text{NH}_2\text{CH}_2\text{COOH}$), one of the amino acids upon which earthly life is based.

Chart: Lewis E. Snyder; redrawn by B.S. Smith

there was no intelligent life on Earth.

This shows that even if there were thousands of civilizations in the universe, the probability of a successful communication would be extremely slight because of the short duration of the "open window."

One must not forget that the range of SETI systems is very limited, reaching only part of our galaxy. The fact that there are a near infinite number of additional galaxies in the universe is irrelevant as far as SETI projects are concerned.

SETI Success: An Improbability of Astronomic Dimensions

What conclusions must we draw from these considerations? No less than six of the eight conditions to be met for SETI success are improbable. When one multiplies these six improbabilities with each other, one reaches an improbability of astronomic dimensions.

Why are there nevertheless still proponents of SETI? When one looks at their qualifications, one finds that they are almost exclusively astronomers, physicists and engineers. They are simply unaware of the fact that the success of any SETI effort is not a matter of physical laws and engineering capabilities but essentially a matter of biological and sociological factors. These, quite obviously, have been entirely left out of the calculations of the possible success of any SETI project.

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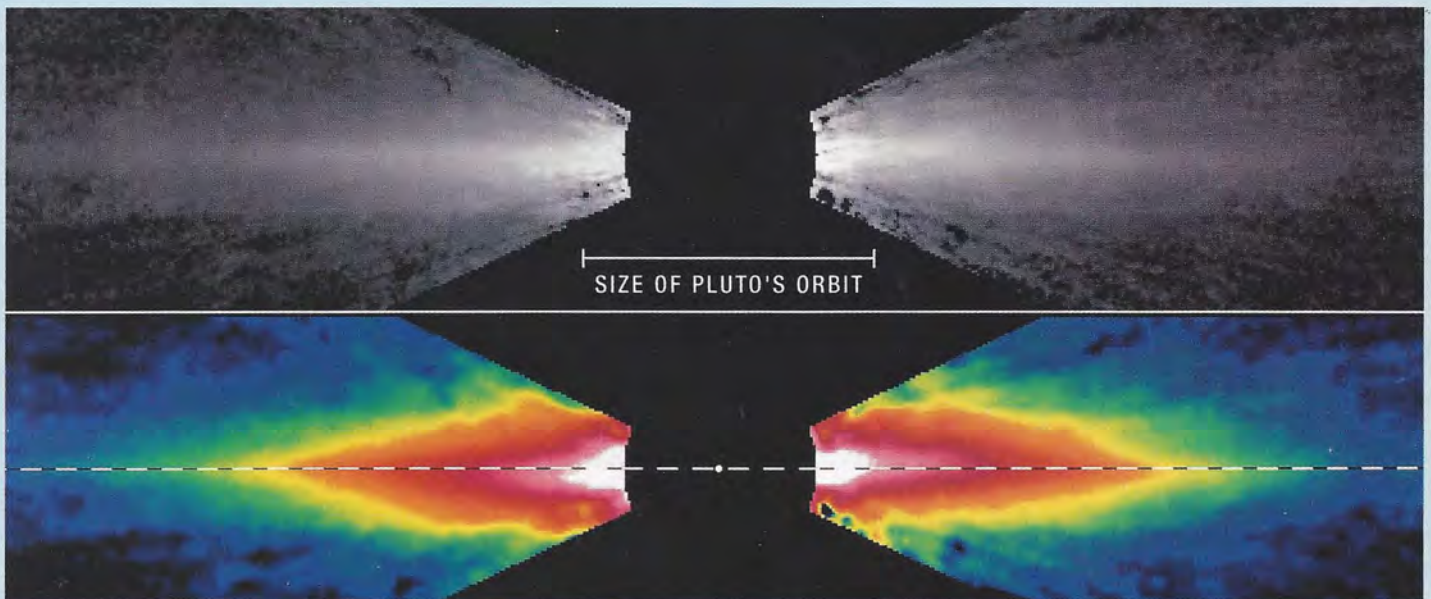
THE ABUNDANCE OF LIFE-BEARING PLANETS

by Carl Sagan

We live in an age of remarkable exploration and discovery. Fully half of the nearby Sun-like stars have circumstellar disks of gas and dust like the solar nebula out of which our planets formed 4.6 billion years ago. By a most unexpected technique—radio timing residuals—we have discovered two Earth-mass planets around the pulsar B1257+12. Apparent jovian planets have been detected around the stars 51 Pegasi, 70 Virginis and 47 Ursae Majoris. A range of new Earth-based and spaceborne techniques—including astrometry, spectrophotometry, radial velocity measurements, adaptive optics and interferometry—all seem to be on the verge of being able to detect jovian-type

world. Consider Venus. But there are means by which, even from the vantage point of Earth, we can investigate this question. We can look for the spectral signature of enough water to be consistent with oceans. We can look for oxygen and ozone in the planet's atmosphere. We can seek molecules like methane, in such wild thermodynamic disequilibrium with the oxygen that it can only be produced by life. (In fact, all of these tests for life were successfully performed by the *Galileo* spacecraft in its close approaches to Earth in 1990 and 1992 as it wended its way to Jupiter [Sagan et al., 1993].)

The best current estimates of the number and spacing of Earth-mass planets in newly forming planetary systems (as George Wetherill reported at the first international conference on circumstellar habitable zones [Doyle, 1996]) combined with the best current estimates of the long-term stability of oceans on a variety of planets (as James Kasting reported at that same meeting [Doyle, 1996]) suggest one to two blue worlds around every Sun-like star. Stars much more massive than the Sun are comparatively rare and age quickly. Stars comparatively less massive than the Sun are expected to have Earth-like planets, but the planets that are warm enough for life are probably tidally locked so that one side always faces the local sun. However, winds may redistribute heat from one hemisphere to another on such worlds, and there has



In 1984, astronomers Brad Smith and Rich Terrell discovered a disk of dust 200 billion kilometers (about 120 billion miles) wide surrounding the star Beta Pictoris. This was exactly what was predicted by theories of planetary formation. The innermost region was clear of dust, as if planets orbiting there had swept it up, but there was little else to suggest that there might be planets orbiting that star—until the Hubble Space Telescope returned the images seen here. They reveal that the inner dust disk is warped. This is indirect evidence that a planet roughly Jupiter's size is orbiting the star at a distance that falls within the range found for planets in our solar system. (The dark region in the center of both images is caused by an occulting disk in the telescope.) Images: Chris Burrows, ESA and NASA

planets, if they exist, around the nearest stars. At least one proposal (The FRESIP [Frequency of Earth-Sized Inner Planets] Project, a spaceborne spectrophotometric system) holds the promise of detecting terrestrial planets more readily than jovian ones. If there is not a sudden cutoff in support, we are likely entering a golden age in the study of the planets of other stars in the Milky Way galaxy.

Once you have found another planet of Earth-like mass, however, it of course does not follow that it is an Earth-like

been very little work on their potential habitability.

Nevertheless, the bulk of the current evidence suggests a vast number of planets distributed through the Milky Way with abundant liquid water stable over lifetimes of billions of years. Some will be suitable for life—our kind of carbon and water life—for billions of years less than Earth, some for billions of years more. And, of course, the Milky Way is one of an enormous number, perhaps a hundred billion, other galaxies.

Need Intelligence Evolve on an Inhabited World?

We know from lunar cratering statistics, calibrated by returned *Apollo* samples, that Earth was under hellish bombardment by small and large worlds from space until around 4 billion years ago. This pummeling was sufficiently severe to drive entire atmospheres and oceans into space. Earlier, the entire crust of Earth was a magma ocean. Clearly, this was no breeding ground for life.

Yet, shortly thereafter—Mayr adopts the number 3.8 billion years ago—some early organisms arose (according to the fossil evidence). Presumably the origin of life had to have occupied some time before that. As soon as conditions were favorable, life began amazingly fast on our planet. I have used this fact (Sagan, 1974) to argue that the origin of life must be a highly probable circumstance; as soon as conditions permit, up it pops!

Now, I recognize that this is at best a plausibility argument and little more than an extrapolation from a single example. But we are data constrained; it's the best we can do.

Does a similar analysis apply to the evolution of intelligence? Here you have a planet burgeoning with life, profoundly changing the physical environment, generating an oxygen atmosphere 2 billion years ago, going through the elegant diversification that Mayr briefly summarized—and not for almost 4 billion years does anything remotely resembling a technical civilization emerge.

In the early days of such debates (for example, G.G. Simpson's "The Non-prevalence of Humanoids"), writers argued that an enormous number of individually unlikely steps were required to produce something very like a human being, a "humanoid"; that the chances of such a precise repetition occurring on another planet were nil; and therefore that the chance of extraterrestrial intelligence was nil. But clearly when we're talking about extraterrestrial intelligence, we are not talking—despite *Star Trek*—of humans or humanoids. We are talking about the functional equivalent of humans—say, any creatures able to build and operate radio telescopes. They may live on the land or in the sea or in the air. They may have unimaginable chemistries, shapes, sizes, colors, appendages and opinions. We are not requiring that they follow the particular route that led to the evolution of humans. There may be many different evolutionary pathways, each unlikely, but the sum of the number of pathways to intelligence may nevertheless be quite substantial.

In Mayr's current presentation, there is still an echo of "the non-prevalence of humanoids." But the basic argument is, I think, acceptable to all of us. Evolution is opportunistic and not foresighted. It does not "plan" to develop intelligent life a few billion years into the future. It responds to short-term contingencies. And yet, other things being equal, it is better to be smart than to be stupid, and an overall trend toward intelligence can be perceived in the fossil record. On some worlds, the selection pressure for intelligence may be higher; on others, lower.

If we consider the statistics of one, our

own case—and take a typical time from the origin of a planetary system to the development of a technical civilization to be 4.6 billion years—what follows? We would not expect civilizations on different worlds to evolve in lockstep. Some would reach technical intelligence more quickly, some more slowly, and—doubtless—some never. But the Milky Way is filled with second- and third-generation stars (that is, those with heavy elements) as old as 10 billion years.

So let's imagine two curves: The first is the probable time-scale to the evolution of technical intelligence. It starts out very low; by a few billion years it may have a noticeable value; by 5 billion years, it's something like 50 percent; by 10 billion years, maybe it's approaching 100 percent. The second curve is the ages of Sun-like stars, some of which are very young—they're being born right now—some of which are as old as the Sun, some of which are 10 billion years old. If we convolve these two curves, we find there's a chance of technical civilizations on planets of stars of many different ages—not much in the very young ones, more and more for the older ones. The most likely case is that we will hear from a civilization considerably more advanced than ours. For each of those technical civilizations, there will have been tens of billions or more other species. The number of unlikely events that had to be concatenated to evolve a technical species is enormous, and perhaps there are members of each of those species who pride themselves on being uniquely intelligent in all the universe.

Need Civilizations Develop the Technology for SETI?

It is perfectly possible to imagine civilizations of poets or (perhaps) Bronze Age warriors who never stumble on James Clerk Maxwell's equations and radio receivers. But they are removed by natural selection. The Earth is surrounded by a population of asteroids and comets, such that occasionally the planet is struck by one large enough to do substantial damage.



From what was probably a single progenitor, life on Earth has adapted and evolved into a bewildering variety of forms, with astonishing behaviors that enable these teeming organisms to survive. Consider the sponge: For most of its life, this animal sits attached to one place, sifting its food from seawater flowing through its many cavities. It is not a lifestyle that requires intelligence. But the sponge does possess one remarkable trait. If a sponge is forced through a fine mesh, breaking it into single cells or clumps of cells, the cells will reassemble themselves into another sponge.

Photo: Brian Parker, Tom Stack & Associates

The most famous is the K-T event (the massive near-Earth-object impact that occurred at the end of the Cretaceous Period and start of the Tertiary) of 65 million years ago that extinguished the dinosaurs and most other species of life on Earth. But the chance is something like one in 2,000 that a civilization-destroying impact will occur in the next century.

It is already clear that we need elaborate means for detecting and tracking near-Earth objects and the means for their interception and destruction. If we fail to do so, we will simply be destroyed. The Indus Valley, Sumerian, Egyptian, Greek and other civilizations did not have to face this crisis because they did not live long enough. Any long-lived civilization, terrestrial or extraterrestrial, must come to grips with this hazard. Other solar systems will have greater or lesser asteroidal and cometary fluxes, but in almost all cases the dangers should be substantial.

Radiotelemetry, radar monitoring of asteroids, and the entire concept of the electromagnetic spectrum are part and parcel of any early technology needed to deal with such a threat. Thus, any long-lived civilization will be forced by natural selection to develop the technology of SETI. (And there is no need to have sense organs that "see" in the radio region. Physics is enough.)

Since perturbation and collision in the asteroid and comet belts are perpetual, the asteroid and comet threat is likewise perpetual, and there is no time when the technology can be retired. Also, SETI itself is a small fraction of the cost of dealing with the asteroid and comet threat.

(Incidentally, it is by no means true that SETI is "very limited, reaching only part of our galaxy." If there were sufficiently powerful transmitters, we could use SETI to explore distant galaxies; because the most likely transmitters are ancient, we can expect them to be powerful. This

is one of the strategies of the Megachannel Extraterrestrial Assay [META].)

Is SETI a Fantasy of Physical Scientists?

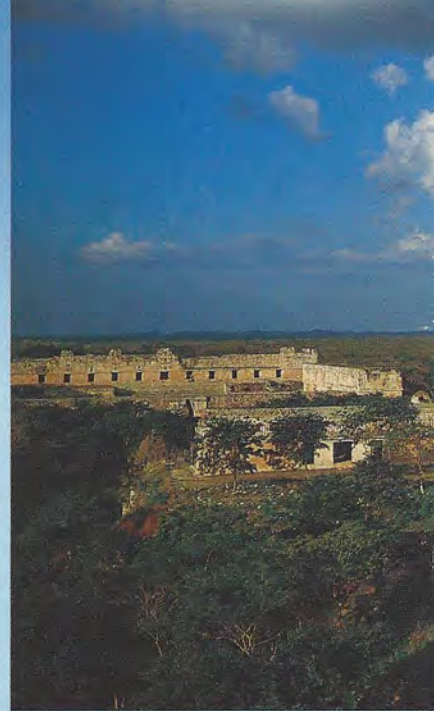
Mayr has repeatedly suggested that proponents of SETI are almost exclusively physical scientists and that biologists know better. Since the relevant technologies involve the physical sciences, it is reasonable that astronomers, physicists and engineers play a leading role in SETI.

But in 1982, when I put together a petition published in *Science* urging the scientific respectability of SETI, I had no difficulty getting a range of distinguished biologists and biochemists to sign, including David Baltimore, Melvin Calvin, Francis Crick, Manfred Eigen, Thomas Eisner, Stephen Jay Gould, Matthew Meselson, Linus Pauling, David Raup and Edward O. Wilson. In my early speculations on these matters, I was much encouraged by the strong support from my mentor in biology, H.J. Muller, a Nobel laureate in genetics.

The petition proposed that, instead of arguing the issue, we look: "We are unanimous in our conviction that the only significant test of the existence of extraterrestrial intelligence is an experimental one. No a priori arguments on this subject can be compelling or should be used as a substitute for an observational program."

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Many civilizations have risen and fallen on Earth, but only one has developed the technology to communicate over interstellar distances. The Mayans, for example, were expert astronomers,

To get a handle on the myriad living things that share this planet, humans name and classify every distinct form they identify. They then clump the life-forms into groups. In one system, there are three main branches of life: the eubacteria, the archebacteria and the eukaryota. The eukaryota are divided into four kingdoms—Protista (single-celled or colonial forms), Animalia (our kingdom), Plantae (plants) and Fungi. This last group is highly successful, but its members are not the sort of life-forms that might evolve intelligence. They are, however, relatively close relations of ours; our evolutionary paths diverged a little more than a billion years ago.

Photo: David M. Dennis, Tom Stack & Associates





using the motion of the heavens as a clockwork for many aspects of their lives. But this knowledge did not save the culture, whose abandoned monuments were swallowed by the jungle life-forms. The Pyramid of the Magician in Uxmal, Mexico, shown here, is a reminder of the short lifetimes of earthly civilizations. Photo: David L. Brown, Tom Stack & Associates

tronic know-how to meet the peril of asteroid impacts is totally unrealistic. How would the survivors of earlier impacts be selected to develop the electronic know-how? Also, the case of Earth shows how impossible the origin of any civilization is unless high intelligence develops first. Earth furthermore shows that civilizations inevitably are short-lived.

It is only a matter of common sense that the existence of extraterrestrial intelligence cannot be established by a priori arguments. But this does not justify SETI projects, since it can be shown that the success of an observational program is so totally improbable that it can, for all practical purposes, be considered zero.

All in all, I do not have the impression that Sagan's rebuttal has weakened in any way the force of my arguments.

Carl Sagan Responds:

The gist of Professor Mayr's argument is essentially to run through the various factors in the Drake equation (see Shklovskii and Sagan, 1966) and attach qualitative values to each. He and I agree that the probabilities concerning the →

Ernst Mayr Responds:

I fully appreciate that the nature of our subject permits only probabilistic estimates. There is no argument between Carl Sagan and myself as to the probability of life elsewhere in the universe and the existence of large numbers of planets in our and other nearby galaxies. The issue, as correctly emphasized by Sagan, is the probability of the evolution of high intelligence and an electronic civilization on an inhabited world.

Once we have life (and almost surely it will be very different from life on Earth), what is the probability of its developing a lineage with high intelligence? On Earth, among millions of lineages of organisms and perhaps 50 billion speciation events, only one led to high intelligence; this makes me believe in its utter improbability.

Sagan adopts the principle "it is better to be smart than to be stupid," but life on Earth refutes this claim. Among all the forms of life, neither the prokaryotes nor protists, fungi or plants have evolved smartness, as they should have if they were "better." In the 28-plus phyla of animals, intelligence evolved in only one (chordates) and doubtfully also in the cephalopods. And in the thousands of subdivisions of the chordates, high intelligence developed in only one, the primates, and even there only in one small subdivision. So much for the putative inevitability of the development of high intelligence because "it is better to be smart."

Sagan applies physicalist thinking to this problem. He constructs two linear curves, both based on strictly deterministic thinking. Such thinking is often quite legitimate for physical phenomena, but is quite inappropriate for evolutionary events or social processes such as the origin of civilizations. The argument that extraterrestrials, if belonging to a long-lived civilization, will be forced by selection to develop an elec-

THE DRAKE EQUATION

With only one example of a technical civilization in front of us, how can we estimate how many such civilizations might exist in our galaxy? In the early 1960s, astronomer Frank Drake took a run at the problem and produced an equation that became famous in SETI circles. The Drake equation attempts to derive N , the number of detectable civilizations around other stars. The equation takes into consideration the following items:

- N_* — the number of stars in the Milky Way galaxy
- f_p — the fraction of stars that have planetary systems
- n_e — the number of planets in a given system that are ecologically suitable for life
- f_l — the fraction of otherwise suitable planets on which life actually arises
- f_i — the fraction of inhabited planets on which an intelligent life-form evolves
- f_c — the fraction of the planets inhabited by intelligent beings on which a communicative technical civilization develops
- f_L — the fraction of a planetary lifetime graced by a technical civilization

Written out, the equation reads:

$$N = N_* f_p n_e f_l f_i f_c f_L$$

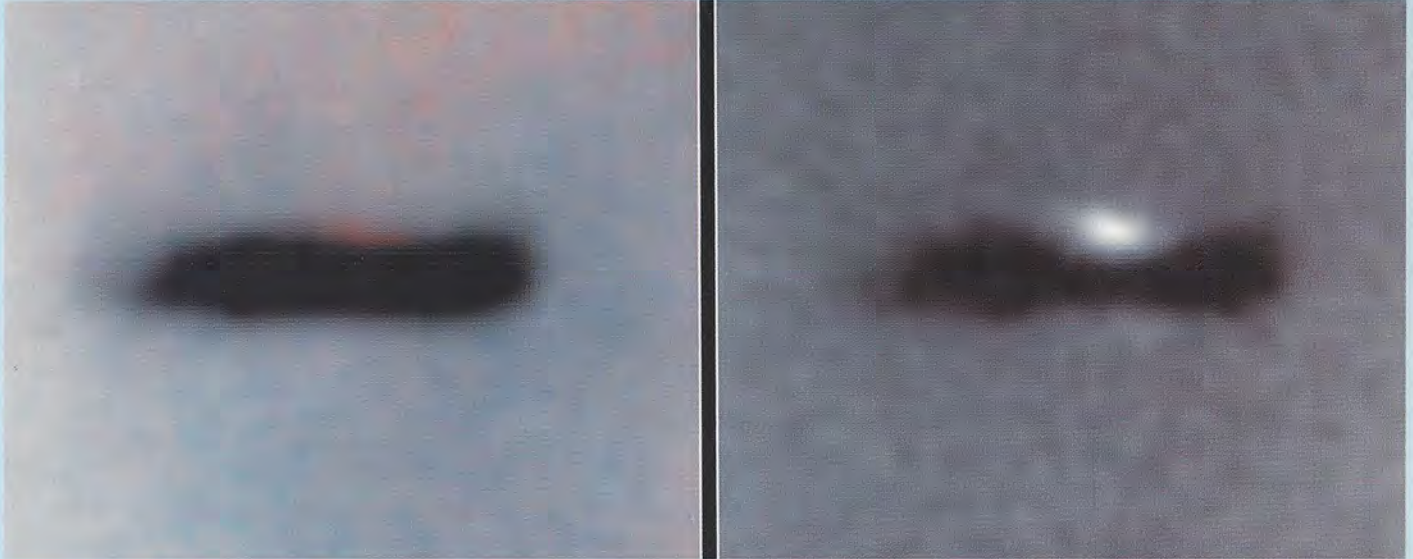
All the f 's are fractions with values between 0 and 1. The values assigned to these elements depend on the presuppositions and assumptions of the person doing the calculation. As you'll note after reading the accompanying debate, for some, N will equal 1; for others, it could be a sizable number.

—Charlene M. Anderson

abundance of planets and the origins of life are likely to be high. (I stress again that the latest results [Doyle, 1996] suggest one or even two Earth-like planets with abundant surface liquid water in each planetary system. The conclusion is of course highly tentative, but it encourages optimism.) Where Mayr and I disagree is in the later factors in the Drake equation, especially those concerning the likelihood

Kanzi has discovered how to manufacture stone tools.

It is true, as Mayr notes, that of the major human civilizations, only one has developed radio technology. But this says almost nothing about the probability of a human civilization developing such technology. That civilization with radio telescopes has also been at the forefront of weapons technology. If, for example, Western European



As far as humans were concerned, protoplanetary disks once existed only in the hypotheses of physicists trying to work out how our solar system formed. But with technological devices like the Hubble Space Telescope, these disks have graduated from the realm of hypothesis to fact. This embryonic solar system, seen edge on, resides around a newborn star in the Orion nebula. On the left, the disk stands out distinctly from the nebula. On the right, seen through different filters, the edges are not so distinct, but we can see a faint glow from the hidden central star. Our solar system may have looked something like this 4.5 billion years ago. Images: Mark McCaughrean, C. Robert O'Dell and NASA

of the evolution of intelligence and technical civilizations.

Mayr argues that prokaryotes and protista have not “evolved smartness.” Despite the great respect in which I hold Professor Mayr, I must demur: Prokaryotes and protista are our ancestors. They *have* evolved smartness, along with most of the rest of the gorgeous diversity of life on Earth.

On the one hand, when he notes the small fraction of species that have technological intelligence, Mayr argues for the relevance of life on Earth to the problem of extra-terrestrial intelligence. But on the other hand, he neglects the example of life on Earth when he ignores the fact that intelligence has arisen here when our planet has another 5 billion years more evolution ahead of it. If it were legitimate to extrapolate from the one example of planetary life we have before us, it would follow that

1. There are enormous numbers of Earth-like planets, each stocked with enormous numbers of species, and
2. In much less than the stellar evolutionary lifetime of each planetary system, at least one of those species will develop high intelligence and technology.

Alternatively, we could argue that it is improper to extrapolate from a single example. But then Mayr’s one-in-50 billion argument collapses. It seems to me he cannot have it both ways.

On the evolution of technology, I note that chimpanzees and bonobos have culture and technology. They not only use tools but also purposely manufacture them for future use (cf. Sagan and Druyan, 1992). In fact, the bonobo

civilization had not utterly destroyed Aztec civilization, would the Aztecs eventually—in centuries or millennia—have developed radio telescopes? They already had a superior astronomical calendar to that of the *conquistadores*. Slightly more capable species and civilizations may be able to eliminate the competition. But this does not mean that the competition would not eventually have developed comparable capabilities if they had been left alone.

Mayr asserts that plants do not receive “electronic” signals. By this I assume he means “electromagnetic” signals. But plants *do*. Their fundamental existence depends on receiving electromagnetic radiation from the Sun. Photosynthesis and phototropism can be found not only in the simplest plants but also in protista.

All stars emit visible light, and Sun-like stars emit most of their electromagnetic radiation in the visible part of the spectrum. Sensing light is a much more effective way of understanding the environment at some distance; certainly much more powerful than olfactory cues. It’s hard to imagine a competent technical civilization that does not devote major attention to its primary means of probing the outside world. Even if they were mainly to use visible, ultraviolet or infrared light, the physics is exactly the same for radio waves; the difference is merely a matter of wavelength.

I do not insist that the above arguments are compelling, but neither are the contrary ones. We have not witnessed the evolution of biospheres on a wide range of planets. We have not observed many cases of what is possible and

what is not. Until we have had such an experience—or detected extraterrestrial intelligence—we will of course be enveloped in uncertainty.

The notion that we can, by a priori arguments, exclude the possibility of intelligent life on the possible planets of the 400 billion stars in the Milky Way has to my ears an odd ring. It reminds me of the long series of human conceits that held us to be at the center of the universe, or different not just in degree but in kind from the rest of life on Earth, or even contended that the universe was made for our benefit (Sagan, 1994). Beginning with Copernicus, every one of these conceits has been shown to be without merit.

In the case of extraterrestrial intelligence, let us admit our ignorance, put aside a priori arguments and use the technology we are fortunate enough to have developed to try and actually find out the answer. That is, I think, what Charles Darwin—who was converted from orthodox religion to evolutionary biology by the weight of observational evidence—would have advocated.

Ernst Mayr Responds:

Since all we deal with are probabilities, most of them extrapolated from a sample of one, let me make a few observations in response to Carl Sagan: (1) We have no evidence that of the enormous number of Earth-like planets “each [is] stocked with enormous numbers of species.” (2) There is a world of difference

between plants photosynthesizing and a civilization developing the necessary theories and instrumentation for electronic communication. (3) Sagan states, “We have not witnessed the evolution of biospheres on a wide range of planets.” The truth is, we have not witnessed it on a single planet outside Earth. (4) I am not talking about the possibility of extraterrestrial intelligence; I am talking about the probability of establishing it with the available means. None of Sagan’s arguments has weakened my argument that it is virtually zero. This is not a conceit but a sober calculation of probabilities. The negative answer we are bound to receive will not tell us anything about the actual possibility of some extraterrestrial intelligence somewhere.

Carl Sagan Responds:

I draw the tentative conclusion that other Earth-like planets have millions of species of life on them from the same data set that leads Professor Mayr to conclude that there are no extraterrestrial technical civilizations. Mayr now concedes (observation number 4 above) that there may be extraterrestrial intelligence. (Maybe even large numbers of planets inhabited by intelligent life?) But he is dubious about whether this intelligence will have developed the means for interstellar radio communication. As I have stressed, there is absolutely no compelling way to evaluate this question except by looking for interstellar radio transmissions. That is what we are doing. ■



One of our interplanetary spacecraft, Galileo, did detect evidence of life on one planet it explored.

Image: JPL/NASA

New Eyes for Mars: Testing Cameras

As we reach for more information about the universe around us, our most powerful sense is vision. Animals have evolved an astonishing capacity to receive and interpret information coming to them in the form of photons. Though not the most acute or sensitive among all species on Earth, human vision is supreme in one respect: combined with the gift of language, it permits us to reason about what we see and to transmit to others not only the facts contained in an image but also its beauty and perhaps its deeper meaning for science. In recent years, technology has opened up a whole new realm of seeing: Antique astronomical telescopes have suddenly become useful again at the frontier of knowledge, and spacecraft, at first limited to what photographic and television cameras could observe, have now been equipped with electronic eyes thousands of times as capable as the best natural ones. The founding technology of this imaging revolution is the charge-coupled diode, or CCD, a microdevice that converts incoming light into little piles of electrons scattered over a focal plane—piles that can be shifted out to the edge of the chip and sent as a data stream to telemetry. With CCD sensors, cameras have become tiny, rugged and very capable. In this article, we report on one such development, a little instrument package that is scheduled to go to Mars. — James D. Burke

The scientific payload of the Russian *Mars '96* mission, scheduled to launch this November, includes two German stereo cameras, the High-Resolution Stereo Camera (HRSC) and the Wide-Angle Optoelectronic Stereo Scanner (WAOSS). (See the January/February 1996 issue of *The Planetary Report* for a story on the *Mars '96* orbiter and the landers and penetrators it will deliver to the martian surface.) Both cameras are CCD line-scan instruments delivering triple panchromatic stereo images. Additionally, HRSC contains four multicolor sensors and two sensors for photometry data.

What They'll Do

The cameras, which will be mounted on the orbiter's ARGUS platform (being developed by Russian space industrial facilities), will scan the surface and the atmosphere. As the spacecraft moves over the planetary surface, the line-scan cameras deliver two-dimensional images for each line sensor. The images of the various sensors overlap and permit the three-dimensional reconstruction of the planetary surface and of cloud structures.

Both cameras use similar focal planes and apply onboard image data compression to allow for deep-space data transmission within the limitations of the telemetry rate. They were designed and developed under the leadership of the

Institute of Planetary Exploration and the Institute of Space Sensor Technology of the Berlin research center of the DLR (German Aerospace Research Establishment), and they were partly financed by DARA, the German space agency.

HRSC will simultaneously acquire high-resolution stereo images of the Mars surface and multicolor and photometry data. WAOSS, on the other hand, will record large-scale surface and atmospheric phenomena in stereo. The ground resolution of images taken at the lowest point in the spacecraft's orbit, 250 kilometers (150 miles), will be 10 meters (30 feet) per pixel for HRSC and approximately 80 meters (260 feet) per pixel for WAOSS. The data from the *Viking* mission contain only limited high-resolution images and singular shots of stereoscopically overlapping images. The camera experiments on *Mars '96*, with simultaneous recording of multisensor data combined with a vast range of operating parameters, open the way toward a thematically oriented interpretation of the martian surface.

Testing the Cameras

We have been intensively testing the cameras to determine their performance and calibration parameters. In addition to standard geometry and radiometry tests, we recorded landscape images from the rooftop of a building at the HRSC industrial prime contractor facility Dornier located at Lake Constance (Germany) near the Swiss Alps. Our purpose was to prove the parallel operations of both cameras and to record test data for the on-ground data processing system.

For these tests, both cameras were mounted on a slowly rotating table. The rotation of the mounting table led to images spanning typically 45 to 90 degrees of the landscape panorama. This rotation corresponds to the conditions to be encountered during the mission to planet Mars. During the months ahead, all images will be fully processed to include radiometric and geometric correction and stereo image processing. Parts of the preprocessing software were developed by the Jet Propulsion Laboratory based on an agreement for the *Mars '96* mission.

Some of the pictures taken during the tests are shown here. They demonstrate the imaging capabilities of the cameras, especially their radiometric quality, geometric fidelity and acuity. All expectations have been met—the decompressed raw data (without radiometric and geometric correction) shown in these panoramas are of an excellent quality.

These images illustrate that the design principles of the stereo cameras have provided remarkable results, giving rise to our hopes that during the *Mars '96* mission many new phenomena will be discovered on planet Mars.

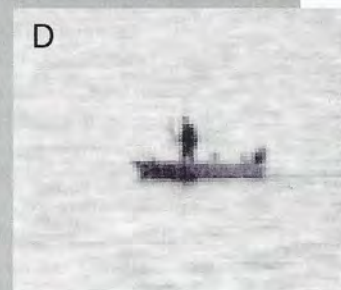
Gerhard Neukum is the principal investigator of the combined HRSC/WAOSS experiment on Mars '96 and director of the Institute of Planetary Exploration of the German Aerospace Research Establishment (DLR).

for the Mars '96 Mission

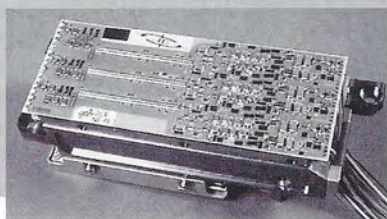
by Gerhard Neukum



Above: Lake Constance and the Swiss Alps served as test subjects for the Mars '96 cameras. This is an image taken by the High-Resolution Stereo Camera (HRSC), with the city of Säntis in the middle ground. The resolution is fine enough to pick out details: B (a city), C (a weather station) and D (a fisherman).



The Wide-Angle Optoelectronic Stereo Scanner (WAOSS) produced the panorama of Lake Constance, the Alps and Säntis (left). The HRSC imaged the same subject (below), with detail fine enough to produce the blowup at bottom.



Charge-coupled devices (CCDs) capture images for spacecraft cameras. This is the focal-plate assembly of three CCD lines for the Mars '96 cameras. Each 4-centimeter-long line contains 5,184 active pixels (picture elements).

Images: DLR Institute of Planetary Exploration, Germany

Fly to Saturn With *Cassini*: Society Members Invited Along

When the *Cassini* spacecraft launches next year, it will be carrying more than a probe and an instrument package to the saturnian system—it will be carrying tens of thousands of signatures from people on Earth. The *Cassini* project team has given everyone who is enchanted by planetary exploration an opportunity to be part of this historic mission.

All Planetary Society members have been invited to fly their names on the spacecraft. Your signature on a postcard will be scanned, digitized and transferred to a CD-ROM, which will be attached to the spacecraft.

The Jet Propulsion Laboratory, which is conducting the *Cassini* mission, has asked The Planetary Society to help with this project, since we have experience in putting names on spacecraft. The two *Mars '96* small stations, launching this November, are each carrying a microdot with the names of all Society members as of October 1993. We will be scanning the *Cassini* signatures and formatting them for transfer to the flight-qualified CD-ROM.

This is a tremendous opportunity for Society members because the *Cassini* mission promises to be one of the most exciting endeavors yet undertaken in planetary exploration.

Cassini will launch to Saturn during a period that lasts from October 6 to November 4, 1997. The spacecraft is one of the largest ever launched, and because of its great mass it will need a few gravity assists to reach its target. It will slingshot by Venus (twice), Earth and Jupiter and use their gravity to boost it on its way. It's scheduled to enter Saturn orbit on July 1, 2004.

While orbiting Saturn, *Cassini* will launch the European Space Agency's *Huygens* probe into the enshrouding atmosphere of the moon Titan. This instrument-laden little craft could help unravel some of the most intriguing mysteries in planetary science.

We know that Titan is surrounded by a thick, mostly nitrogen atmosphere, which the *Voyager* spacecraft's cameras were unable to penetrate. The atmosphere is rich in organic molecules, which on Earth formed the building blocks of

life. It is so heavy with hydrocarbons that a methane and ethane rain may fall upon the surface, collecting in lakes or small seas. The *Huygens* probe may be able to tell us whether or not these hydrocarbon lakes exist.

Huygens will be giving us valuable information about the structure, temperature, pressure and composition of Titan's atmosphere. We think that on Earth, certain organic molecules evolved into living things. Titan is too cold for life as we know it to have evolved. But Reid Thompson and Carl Sagan showed that an average spot on Titan has seen liquid water for about 1,000 years from cometary impact. By studying this atmosphere rich in the building blocks of life, we may better understand how we came to be.

Titan is just one among many saturnian moons that *Cassini* will investigate. The large icy satellites Phoebe, Iapetus, Rhea, Dione, Tethys, Enceladus and Mimas will be among its primary targets, and it will make passes by many of the smaller moons.

Saturn is, of course, most famous for its spectacular set of rings. The *Voyagers* discovered that the rings are made of thousands upon thousands of ringlets, composed of rock and ice, that are shaped and constrained by the gravity of known moons beyond the rings as well as by yet-to-be-discovered moonlets within the rings. To understand the dynamics of this strange and beautiful system will be a prime goal of the *Cassini* mission.

The tour past the planet, its rings and its retinue of satellites is scheduled to last for four years and about six dozen orbits.

If enough propellant is left, and the funding can be found, the mission could be extended for several more orbits.

So, imagine your name flying first through the inner solar system, past Venus and your home world, then out past Jupiter to the enchantingly beautiful worlds of Saturn. There it will orbit for decades, until the spacecraft runs out of attitude-control fuel. Then *Cassini* will slowly begin to spin, gathering speed until it breaks apart. The CD-ROM will continue to orbit Saturn, joining the rings and moons as part of this glorious planetary system.

—Charlene M. Anderson

How You Can Fly to Saturn With *Cassini*

If you would like your name to be included on the CD-ROM that will fly to Saturn on board the *Cassini* spacecraft, here's what you have to do:

1 Sign your name on the non-address side of a plain postcard. Please use a dark ink that can be easily scanned.

2 Mail the card to:
Cassini Program
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109-8099

3 Signatures will be accepted until January 1, 1997, or until the CD-ROM is full.



World Watch

by Louis D. Friedman

Moscow—Roald Kremnev, director of the Babakin Center of NPO Lavochkin, the Russian space agency center responsible for the *Mars '96* spacecraft, told a February meeting of the project's international science team that "*Mars '96* will be launched on schedule—I can guarantee that."

Kremnev's remarks buoyed the spirits of the group of some 50 scientists. They had assembled for what they hoped would be the final pre-project science review for the mission, originally scheduled for a 1994 launch. *Mars '96* is now scheduled to launch between November 12 and 22, 1996, with a large orbiter, two penetrators and two small stations. More than 30 scientific experiments are planned (see the January/February 1996 issue of *The Planetary Report*). The mission will also carry the *Visions of Mars* CD, prepared by The Planetary Society, along with its label containing all Society members' names as of October 15, 1993.

Several of the instruments are late. The most notable concern has been the steerable ARGUS platform for the TV system. It is an ambitious, highly accurate and maneuverable platform being developed in Russia with strong support from the German space agency. The Germans are also providing the TV system. (See page 14 in this issue.) The leader of its development, G.A. Avanesov, reported that, despite development problems, the platform is undergoing final tests and is expected to be ready on time for the mission.

Final integration and checkout will occur at the Baikonur Cosmodrome launch area in Kazakhstan, where the

small nuclear power heaters for the small stations will also be placed on the spacecraft. The spacecraft will be shipped to Baikonur in September.

Pasadena, CA—The Mars *Pathfinder* and *Global Surveyor* spacecraft went through their final assembly checkouts before the space qualification system tests. Both spacecraft are on schedule for their launches at the end of this year—during the November 6–26 period for *Global Surveyor*, December 2–25 for *Pathfinder*. *Global Surveyor* is being built and tested at Lockheed Martin Astronautics near Denver, Colorado; *Pathfinder*, at the Jet Propulsion Laboratory in Pasadena. They will be shipped to Cape Canaveral in September.

Washington, DC—NASA announced that for the first time ever a Russian experiment will be included on a United States planetary mission. Under the Mars Together agreement between the US and Russia, a LIDAR experiment developed by longtime Society colleague Viacheslav Linkin of the Russian Academy of Sciences Space Research Institute (IKI) will fly on the Mars Surveyor lander scheduled to launch in January 1999. The LIDAR will look for dust and aerosols in the martian atmosphere.

Russian experimenters have agreed to include a Mars Microphone proposed by The Planetary Society in the LIDAR package. This instrument will be able to record sounds of wind, dust and electrical discharges in the atmosphere, as well as spacecraft noises. The microphone will be built by IKI in Moscow, and by students at the University of California,

Berkeley, under the direction of Janet Luhmann. IKI will integrate the microphone into the LIDAR flight experiment. The Planetary Society will develop educational and public involvement programs to share in this opportunity to listen for "sounds of Mars."

Washington, DC—Just as the 1996 budget for NASA was finally passed (five months into the fiscal year), the proposed budget for fiscal 1997 was submitted by President Clinton. The final 1996 NASA appropriated budget was \$14.2 billion. President Clinton's 1997 recommendation is \$13.7 billion. (Both amounts are fiscal 1997 dollars.)

The Planetary Society is the only independent public group lobbying for space exploration. Last year, in Congress and on national television news shows, our group was repeatedly cited as proof of support from outside the space program—that is, from those not making their living or otherwise profiting from aerospace business. In these days of budget cutting, this support is crucial. Please write or call your congressional representative and/or senators today. Tell him or her that you want no more cuts in the NASA budget, and that you support planetary exploration. Identify yourself as a member of The Planetary Society—it will help our advocacy.

Louis D. Friedman is Executive Director of The Planetary Society.

Correction: The dates given in an earlier World Watch for the Mars Surveyor orbiter and lander launches were incorrect. The orbiter will launch in December 1998; the lander, in January 1999.

News and Reviews

by Clark R. Chapman

The human brain categorizes. From babyhood, we organize ourselves in our environment by placing things into bins with names. It is so automatic that we don't realize how profoundly it affects how we see and think about the world. As a freshman in college, I labored on an essay on a topic assigned to the class: "What Is a Table?" The apparently simplistic question raises bewildering complexities, reflecting our individual natures, experiences and cultural backgrounds, as well as our hardwired mental apparatus.

Though essential, categorization often leads us astray. We naturally think in stereotypes, but they are inaccurate and even harmful when applied, without qualification, to individual people or things. It is especially problematical if assigning something to a category implicitly or explicitly ranks it.

Two recent issues in the world of planetary science come to mind. One concerns whether Pluto is a planet. Another involves a still-unfolding story about whether comet Hyakutake will be known as the comet of the year, comet of the century or something in between. Unlike questions of nomenclature (what proper name to assign to a crater, or whether to call the comet "Hyakutake" or the obscure "C/1996 B2" advocated by official name-giver Brian Marsden), the categories to which we assign Pluto or a comet affect not only the popular conception of these bodies, but also how scientists understand them.

Cometary Pecking Order

Where does comet Hyakutake rank? No two comets are alike. In 1965, I saw comet Ikeya-Seki's searchlight-like tail stretching across the sky. When its head passed very near the Sun, the comet outshone everything in the sky (besides the Sun and the Moon), but few could

see it well in the Sun's glare. Comet West, in the mid-'70s, was brighter than Hyakutake, but what does one say about a comet that hovered in the morning sky when ordinary folk were asleep? Before the waxing Moon interfered, Hyakutake passed by the handle of the Big Dipper, visible to all before bedtime. A couple of nights later, observers staying up after moonset away from city lights could see the diaphanous tail spilling from Hyakutake's radiant head near the North Star into the Dipper's bowl.

I still think of comet Shoemaker-Levy 9 as the comet of the century, despite requiring a telescope to see its fragments or the dark bruises it left on Jupiter's face. For a naked-eye *visual* spectacle, after watching it from atop 10,000-foot Mount Graham, I personally rank Hyakutake above two bright comets of my youth as well as later ones (Ikeya-Seki, Bennett, West, Levy). Of course, it vastly outperformed the infamous dud Kohoutek and the predicted-to-be-disappointing Halley. Moreover, Hyakutake may have been the largest object in centuries to pass so close to Earth. Next spring, we can all appreciate the individual traits of yet another of the diverse components of our solar system—the even larger comet called Hale-Bopp.

Pipsqueak or Planet?

Is Pluto a planet? Newspapers in 1930 said so when Clyde Tombaugh discovered it. But lately some renegade astronomers threaten to downgrade it. Thanks to a media "bubble" in March, coincidentally confused by sloppy journalistic coverage of the near-simultaneous release of Hubble Space Telescope images of Pluto, millions of schoolchildren may forever doubt that Pluto is a planet.

Pluto is far away and difficult to study. Originally thought to be Earth-

sized, Pluto has shrunk over the years—not actually, of course, but ever-improving measurements show that it is small. One scientist jokingly published a graph of Pluto's dwindling size versus year and "predicted" that Pluto would soon afterward shrink to zero! Since the late 1980s, we have known just how big Pluto is—bigger than the largest asteroid but much smaller than even our Moon.

In a culture where "small is beautiful" is a minority perspective, Pluto's size has been a problem, notwithstanding discovery of its unusually large moon, Charon, which is half Pluto's size, leading some to call Pluto a "double planet." For a while, Pluto was thought to be an escaped satellite of Neptune, since its orbit crosses inside Neptune's orbit. That planet-scuttling theory is now in disfavor, but Pluto as a would-be giant comet is on the rise. Technically, Pluto cannot be a comet since it lacks a tail. But there is no doubt that Pluto would be the comet of the millennium if its chaotic orbit eventually brought it close to the Sun, so that its ices evaporated.

The main thing is that Pluto is Pluto, and a very interesting world it is! The more we learn about it, the more its mysteries cry out for a fast Pluto flyby spacecraft mission. If our developing knowledge of Pluto, of comets, of Kuiper belt objects and of other stray objects in the outer solar system seems to blur the boundaries of our categories a bit, maybe that is a refreshing thing—we can realize that the solar system is a fascinating, complex place and that our stereotypes about planets must respond flexibly to our new knowledge. Is Pluto a planet? A rose by any other name would smell as sweet.

Clark R. Chapman is an institute scientist at the Boulder, Colorado, office of Southwest Research Institute.

Society News

From the Resource Center

The response to our Resource Center survey, published in the November/December 1995 issue of *The Planetary Report*, has been terrific. Members of The Planetary Society are also members of the information age! The responses are being analyzed, and we will report on the results soon. We have received 1,850 responses thus far. (The survey continues—you can find it at our World Wide Web site, <http://planetary.org/tps/>, or write or call us for a copy.)

The response to our call for volunteers to help maintain our Web site has also been terrific. Nearly 100 people have joined our corps of Web watchers! Thanks to all who have generously donated their time and expertise. Right now, we're busy beta testing the Society's new and improved Web site, currently in the last stages of a major reconstruction. The site will feature enhanced graphics and a new architecture to make it easier for you to access our on-line resources.

Resources available on-line increase daily. Of special interest is the Great Space Place, with links to just about all space interest information on-line. You can also find an updated list of planetary missions planned for the next decade.

The Resource Center is not limited to on-line information. We recognize that, for all its growth, Internet access is still difficult for most people around the world, and so we continue to supply printed material as much as we can. (If you do not have Web access and want the aforementioned planetary mission list, contact Society headquarters at tps.km@genie.geis.com, or call us at 818-793-5100.) —*Kari Magee, Resource Center Manager*

Sri Lanka Workshop

Led by Society special consultant and Jet Propulsion Laboratory planetary

scientist Adriana Ocampo, the latest in a series of space science workshops cosponsored by The Planetary Society, the United Nations and the European Space Agency took place in Sri Lanka in January of 1996. This year, the Society sponsored the participation of Duncan Steel of Australia, who spoke about near-Earth objects. We also provided educational materials. Society advisor Arthur C. Clarke gave the keynote speech. —*Louis D. Friedman, Executive Director*

Space Travel and Radiation Risk

On May 29, 1996, at the Crystal City Marriott in Arlington, Virginia, scientists, radiation biologists, public health professionals and astronauts will discuss radiation risk and spaceflight. The symposium is being conducted by the National Council on Radiation Protection and Measurements (NCRP) and is supported by NASA. There is no registration fee, and all are invited to attend. If you're interested in getting firsthand information on this important issue, this is the place to go.

For more information, please contact Laura Atwell of NCRP at 301-657-2652, or coordinator Dade W. Moeller at 919-633-3352. —*Charlene M. Anderson, Director of Publications*

Teachers, Send Your Kids to Mars

Beginning in September 1996, the Arizona Mars K-12 Education Program will produce and distribute MarsLink in a new, mini-magazine format. The Society originally developed MarsLink as a packet of educational materials to teach students about Mars science.

Made possible by Society members and the Kenneth T. and Eileen L. Norris Foundation, MarsLink is distributed free to teachers. For information on how you and your students can receive it, contact Kenneth Edgett at

edgett@esther.la.asu.edu or write him at the Department of Geology, Arizona State University, Box 871404, Tempe, AZ 85287-1404. —*Michael Haggerty, Information Services Manager*

Annual Audit Completed

The firm of Martin Werbelow and Company has completed its yearly audit of The Planetary Society. The firm determined that the Society's 1995 financial statement was in conformity with generally accepted accounting principles.

Copies of the financial statement, which includes a report on member-donations restricted to special use, are available on request. —*Lu Coffing, Financial Manager*

Planning Your Vacation?

If you'd like to try something really different—let's say a visit to the world's largest radio telescope, or maybe a firsthand view of the *Mars '96* launch—take your vacation with The Planetary Society. We have exciting tours to Tucson, Arizona; Arecibo, Puerto Rico; Gubbio, Italy; Orlando, Florida; and Baikonur, Kazakhstan. Call me at Planetary Society headquarters (818-793-5100) for details. —*Cindy Jalife, Manager of Program Development*

More News

The Mars Underground News:
Launches to Mars...the Case for Mars conference...current Mars missions.

The Bioastronomy News:
Newly discovered extrasolar planets... debate over SETI...the optical search for extraterrestrials.

The NEO News:
NEAR launches...guarding Earth from near-Earth objects (NEOs)... comets, asteroids and meteoroids.

For more information on these newsletters, please contact Planetary Society headquarters; see page 2.

Questions and Answers

Do clocks and watches work the same in space as they do on Earth?

—Emmanuel Garsd (age 7),
Buenos Aires, Argentina

Because modern clocks and watches are designed to be as free of environmental effects as possible, they do indeed work the same in space and on Earth.

The common clock or watch that you buy in a department store today probably depends on a microelectronic circuit powered by a battery. It will run the same practically anywhere, although one can certainly find extreme environments that would affect it—for example, Jupiter's radiation belts. But such clocks and watches are a fairly recent development.

Timekeeping was invented several thousand years ago in response to the needs of agriculture and the importance of the changing day and seasons. Whatever the actual historical process, and wherever in the world it occurred, the definition of time must have been asso-

ciated somehow with techniques to measure it. Some of the early clocks were the sundial and the water clock or clepsydra (literally, "water thief"), which measures a time interval rather than absolute time.

Perhaps a little later, the hourglass was invented. It was based on the pouring of fine sand through a tiny hole from an upper into a lower chamber. Although it operates on the same principle as the clepsydra, it is more accurate. But because hourglasses depend on gravity, they will not work in a spaceship in orbital free fall.

Another device that depends on gravity, and hence would not work the same in space and on Earth, is the pendulum clock. Prior to the electronic clock, it was the most accurate clock you could buy, both for keeping absolute time and for timing an interval.

So here are examples where clocks definitely do not work the same on Earth and in space. However, it is by the nature of their design that they fail, not because

of some fundamental physical principle.

Clocks are based on counting the cycles of something—the cycles of the day (Earth's rotation), cycles of a month and year (the orbital periods of Earth and the Moon), the swinging of a pendulum or, for electronic clocks, the natural frequency of a quartz crystal.

However, none of these cycles is nearly as uniform as the fundamental frequencies of the atom. How do we know? Mostly it is as a result of atomic theory, but also in practice all good atomic clocks keep better time with respect to each other than they do with respect to the natural cycles of Earth rotation and orbital motion.

An exception is the regular pulse-arrival times from rapidly rotating neutron stars with periods of a few thousandths of a second, the so-called millisecond pulsars. Their rotation seems at least as regular as the atomic clocks they are compared against—possibly more so. They can rightfully be considered celestial clocks.

Factinos

Geoffrey W. Marcy of San Francisco State University and R. Paul Butler of San Francisco State and the University of California, Berkeley, have discovered two new, unseen planets orbiting nearby stars. The scientists found the new planets around Sun-like stars—70 Virginis in the constellation Virgo and 47 Ursae Majoris in Ursa Major, better known as the Big Dipper. Although both stars are visible to the naked eye, the planets are too small, and thus too faint, to be seen against the glare of their parent bodies.

These are the positions of the newly discovered planets orbiting 70 Virginis and 47 Ursae Majoris, as well as the recently detected planet at 51 Pegasi, in relation to their stars. Compare their positions to those of four familiar planets and their Sun.

Illustration: Geoffrey W. Marcy and R. Paul Butler, San Francisco State University; redrawn by B.S. Smith

Marcy and Butler monitored the motion of 120 stars, including 70 Virginis and 47 Ursae Majoris, for over seven years with a spectrograph mounted on a 3-meter (120-inch) telescope at California's Lick Observatory. A recent com-

puter analysis revealed that light from the two stars appears alternately redder and bluer, indicating that they move back and forth along the line of sight to Earth. According to Marcy, in each case the wobbles describe a nearly perfect



But current timekeeping is based on atomic clocks, not pulsars, and any deviation of these atomic clocks from uniformity is attributed to their construction and environment, not to an inherent instability of the atomic frequency. Therefore, since 1967 the second of time has been defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom. This is a very technical definition, but I include it to show that we base timekeeping on an atomic frequency—not on the motion of heavenly bodies, as in the past. An ideal clock would record the time in seconds as defined by this atomic radiation.

From the viewpoint of a person traveling in space, an ideal clock carried on the spacecraft would run at the same rate everywhere. A three-minute egg would always take three minutes. The astronaut's pulse rate—for example, 75 beats per minute as recorded by the clock—would be the same and the astronaut's life expectancy would not change as recorded by the clock.

However, the theory of relativity tells us that with respect to another ideal clock carried on a second spacecraft, or with respect to a clock left at rest on the surface of Earth, the rates would be different. This is where our common sense fails us. Our first inclination is to dismiss such a conclusion as some misunderstanding of how we compare clocks

when they are in motion with respect to one another. But the predictions are real.

Atomic clocks tuned to the cesium frequency are almost ideal clocks. They are accurate to approximately one-millionth of a second over the period of a year, and they clearly demonstrate that they run at different rates depending on their relative motions. In 1971, J.C. Hafele and R. Keating each took a cesium-beam atomic clock on commercial aircraft around the world. One went eastward and the other westward so that their velocities about Earth would be different. When they came back together to compare clocks, not only did they not agree on the absolute time, they differed by the amount predicted by relativity to an accuracy of about 10 percent.

There is also a gravitational effect on clock rates. An atomic clock kept at the National Bureau of Standards in Boulder, Colorado, at an altitude of about 1,650 meters (5,400 feet) gains about five-millionths of a second per year on a similar clock kept at the Royal Greenwich Observatory in England at an altitude of about 25 meters (80 feet), again in agreement with relativistic predictions.

When atomic clocks are flown in satellites, there is a combination of the motion effect verified by airplane flights and the gravitational effect measured between two clocks at different heights above Earth's surface. As a clock is carried to higher elevations, the gravitational effect causes it to run faster than

a comparable clock at sea level. On the other hand, the speed of an orbiting satellite is slower at higher altitudes, and consequently the clock does not slow as much with respect to a clock on Earth. The two effects cancel at an altitude equal to one-half Earth's radius, or about 3,189 kilometers (roughly 2,000 miles) and the orbiting clock runs at the same rate as on Earth. Below this altitude, the satellite clock runs slow; above it, the clock runs fast, again in comparison to a clock on Earth.

Because our modern methods of timekeeping rely on standard cesium-beam clocks on Earth and similar clocks carried in satellites (the Global Positioning System or GPS), it is important to apply these small relativistic corrections at all stages of any time transfer between standard clocks and a local clock, whether measuring absolute time or time intervals.

Fortunately, the people who implemented the GPS made it easy on the user by including all the relativistic corrections. As a result, all that is required to synchronize your local clock with standard atomic time is a satellite receiver and a knowledge of your location on Earth. An error of 5 to 10 meters (16 to 33 feet) in your location will cause a timing error of about 20-billionths of a second over one day, perhaps of small concern.

—JOHN D. ANDERSON,
Jet Propulsion Laboratory

sine curve—a motion so periodic that only an unseen object pulling the star toward and away from Earth can account for it.

The researchers report that the body orbiting 47 Ursae Majoris has a mass about 3.5 times that of Jupiter. It circles the star about twice the distance of Earth from the Sun and takes roughly three years to complete a revolution. Its surface temperature would be minus 90 degrees Celsius (minus 130 degrees Fahrenheit) but its atmosphere could contain liquid water, the scientists calculate.

In contrast, the object at 70 Virginis is about eight times as massive as Jupiter. Its orbit lies about half Earth's distance from the Sun and it has a surface temperature of 83 degrees Celsius (about 180

degrees Fahrenheit), the same as tepid tea. "This planet could conceivably have rain or even oceans [of liquid water]," Marcy said.

—from *Science News*

Scientists believe that they have discovered, in the African country of Chad, a chain of impact craters that suggests that ancient Earth may have been hit by a large, fragmented comet or asteroid similar to comet Shoemaker-Levy 9, which slammed into Jupiter in 1994.

The craters were discovered in radar images of Earth taken by the Spaceborne Imaging Radar C/X-band Synthetic Aperture Radar (SIR-C/X-SAR) that flew on the space shuttle in 1994. The images reveal two new craters adjacent to a previously known impact site

called Aorounga.

"The Aorounga craters are only the second chain of large craters known on Earth, and were apparently formed by the breakup of a large comet or asteroid prior to impact," said Adriana Ocampo, a geologist from the Jet Propulsion Laboratory. "With ground confirmation (which has not yet occurred), this second chain will provide valuable data on the nature and origin of small bodies that cross Earth's orbit."

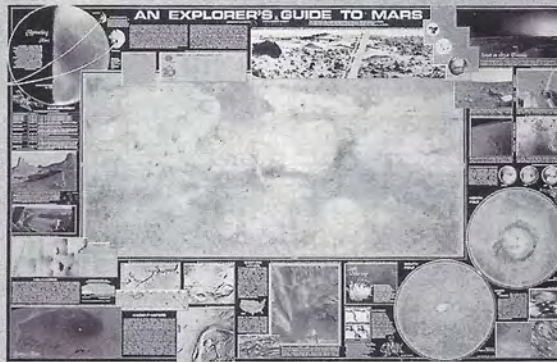
"These could very well be impact structures, but we don't have the kind of evidence we need to catalogue them yet," said John McHone, a SIR-C science team member from the University of Arizona who has studied impact craters for more than 20 years.

—from the Jet Propulsion Laboratory



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In July 1994, a fragmented comet will strike the planet Jupiter. For more information about this once-in-a-thousand-year event, call The Planetary Society.

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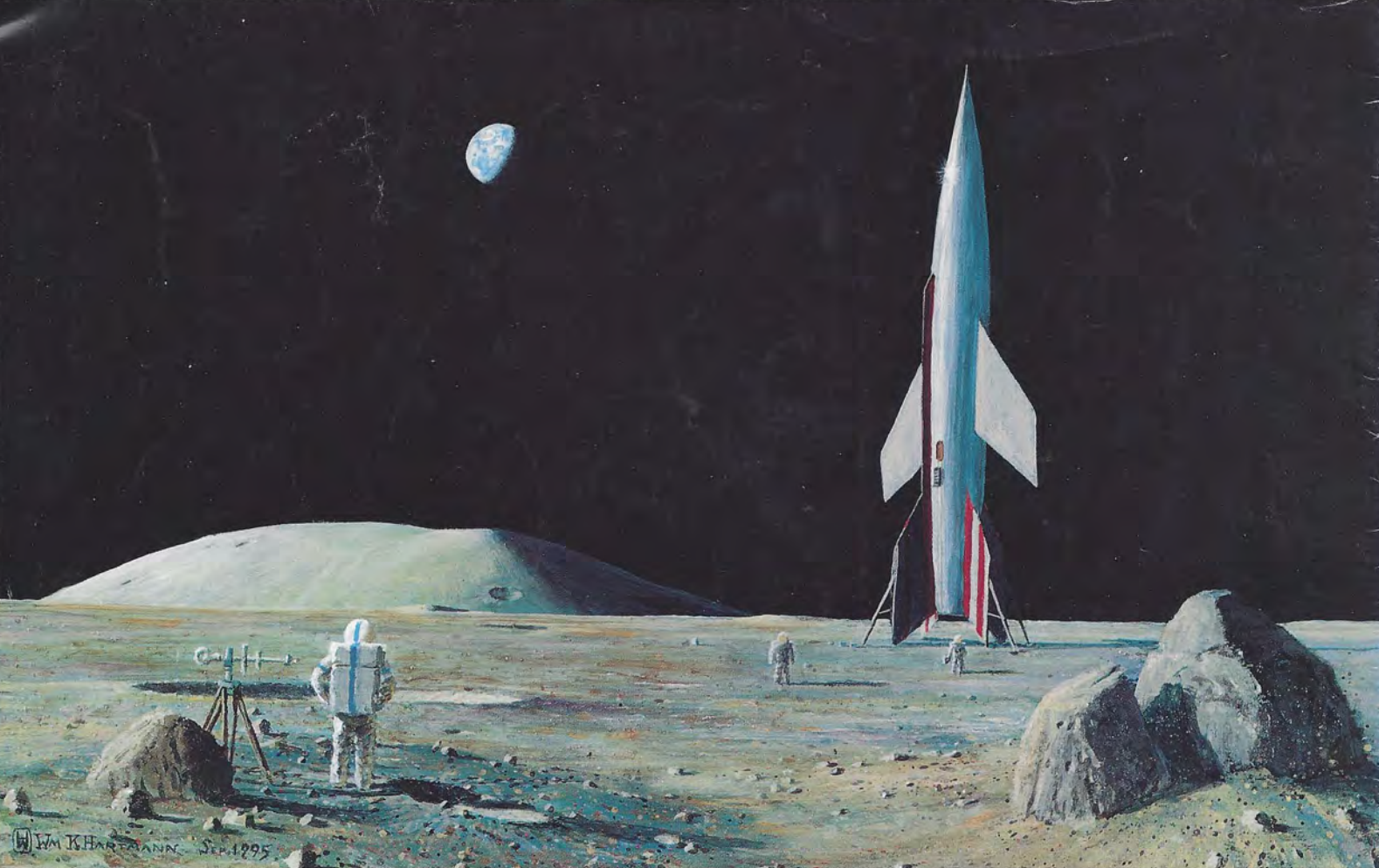


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"How It Might Have Been: Homage to Chesley Bonestell," by William K. Hartmann, was inspired by mid-century pioneers' visions of exploration: Chesley Bonestell and Willy Ley designed this spacecraft, which appeared on the cover of their 1949 book, *The Conquest of Space*. The design drew from German V-2 experiments and the early spaceflight ideas of Wernher von Braun and his team. "That cover painting was one of the most influential in the history of space travel," says Hartmann. "From personal interviews, I know that many of the people who worked on the *Apollo* program were inspired by that book, which they had as teenagers. "Bonestell's original painting showed this rocket on a very craggy Moon, which is how most people visualized the lunar surface before *Apollo*. Had the von Braun-Ley-Bonestell ideas been practical, the Moon landings might have looked like this."

William K. Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Arizona, and a participating scientist on the Mars *Global Surveyor* mission. He is also continuing his career as a writer and space artist.

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