

# THE FUTURE OF Space Exploration

*A Guide to the Voyages Unveiling the Cosmos*

## I SPACEFLIGHT TODAY

### 4 The Flagships of the Space Fleet

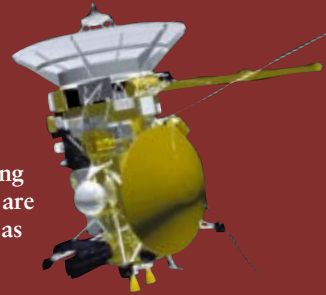
In recent years, a fleet of extraordinary spacecraft has blasted off to explore the solar system. Here is a look at some of the most remarkable vessels ever sent into space and their trailblazing missions.

### 18 Key Space Explorations of the Next Decade

### 20 The International Space Station: A Work in Progress

*Tim Beardsley*, staff writer

The construction of a 500-ton orbiting laboratory will be one of the biggest engineering projects to date. But delays and cost overruns are prompting a redesign of the space station just as the assembly process is beginning.



### 24 A SCIENTIFIC AMERICAN Debate Robots vs. Humans: Who Should Explore Space?

**Unmanned spacecraft** are exploring the solar system more effectively than astronauts are. Recent advances in robotic technology are allowing probes to go to new places and gather more data.

*Francis Slakey*

**Astronaut explorers** can perform science in space that robots cannot. Humans are needed to study planets and moons in detail and to repair scientific instruments and other hardware.

*Paul D. Spudis*

## II EXPLORING MARS

### 32 The Mars Pathfinder Mission

*Matthew P. Golombek*

NASA's Pathfinder spacecraft and the versatile Sojourner rover found evidence that Mars was once a warmer and wetter planet. They also proved that a low-cost space mission could make scientific breakthroughs and delight the public.

### 40 What's Next for Mars

*Glenn Zorpette*, staff writer

In the coming decade, NASA and its European partners plan to send a series of unmanned probes to the Red Planet. The program of exploration will culminate with a mission to bring Martian soil samples to Earth by 2008.

### 46 Sending Humans to Mars

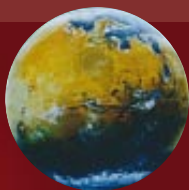
*Robert Zubrin*

Astronauts could safely travel to Mars in the next 10 years using current technologies. The president of the Mars Society outlines a plan for a low-cost manned mission to the Red Planet.

### 52 Bringing Life to Mars

*Christopher P. McKay*

With a 100-year engineering effort, we could transform Mars into a planet where plants from Earth could survive. But would the greening of Mars be ethical?





ABOUT THE COVER: The Stardust spacecraft's planned rendezvous with a comet was painted by mission artist B. E. Johnson.



# III SPACEFLIGHT TOMORROW

## 58 The Way to Go in Space *Tim Beardsley, staff writer*

Spacecraft will need cheaper launches and more powerful propulsion systems to go to the next stage of exploration. Aerospace companies are designing new launch vehicles, and researchers are testing futuristic engines first imagined by science-fiction writers.

## 62 Air-Breathing Engines *Charles R. McClinton*

## 66 Highways of Light *Leik N. Myrabo*

## 70 Compact Nuclear Rockets *James R. Powell*

## 64 Space Tethers *Robert L. Forward and Robert P. Hoyt*

## 68 Light Sails *Henry M. Harris*

## 72 Reaching for the Stars *Stephanie D. Leifer*

## 76 The Best Targets for Future Exploration

Where should we go next? The options are nearly endless. Presented here are some of the most exciting missions currently under consideration, including voyages to the sun, the inner planets and Pluto.

## 88 Interstellar Spaceflight: Can We Travel to Other Stars?

*Timothy Ferris*

Journeys to other stars may be possible, but the cost would be exorbitant. Sending small unmanned probes might be the most practical choice. They could even be used to create a galactic communications network.

## 92 Making Money in Space

*Mark Alpert, issue editor*

The space age won't really take off until businesses figure out ways to earn profits in orbit. Forward-looking entrepreneurs are exploring opportunities in space tourism, asteroid mining and research missions financed in part by commercial sponsors.

## 96 New Satellites for Personal Communications

*John V. Evans*

The satellite communications business is the most successful space industry by far. A new generation of satellites in low-Earth orbit promises to bring cellular telephone service to the most remote parts of the globe.

## 100 Tapping the Waters of Space

*John S. Lewis*

The first step in colonizing the solar system is finding an inexpensive source of spacecraft propellant. Surprisingly, the cheapest fuel for interplanetary voyages may be the water ice contained in near-Earth asteroids.



# IV THE BEST USE OF SPACE

## 104 Exploring Space on the Internet

A list of sites on the World Wide Web devoted to space exploration.