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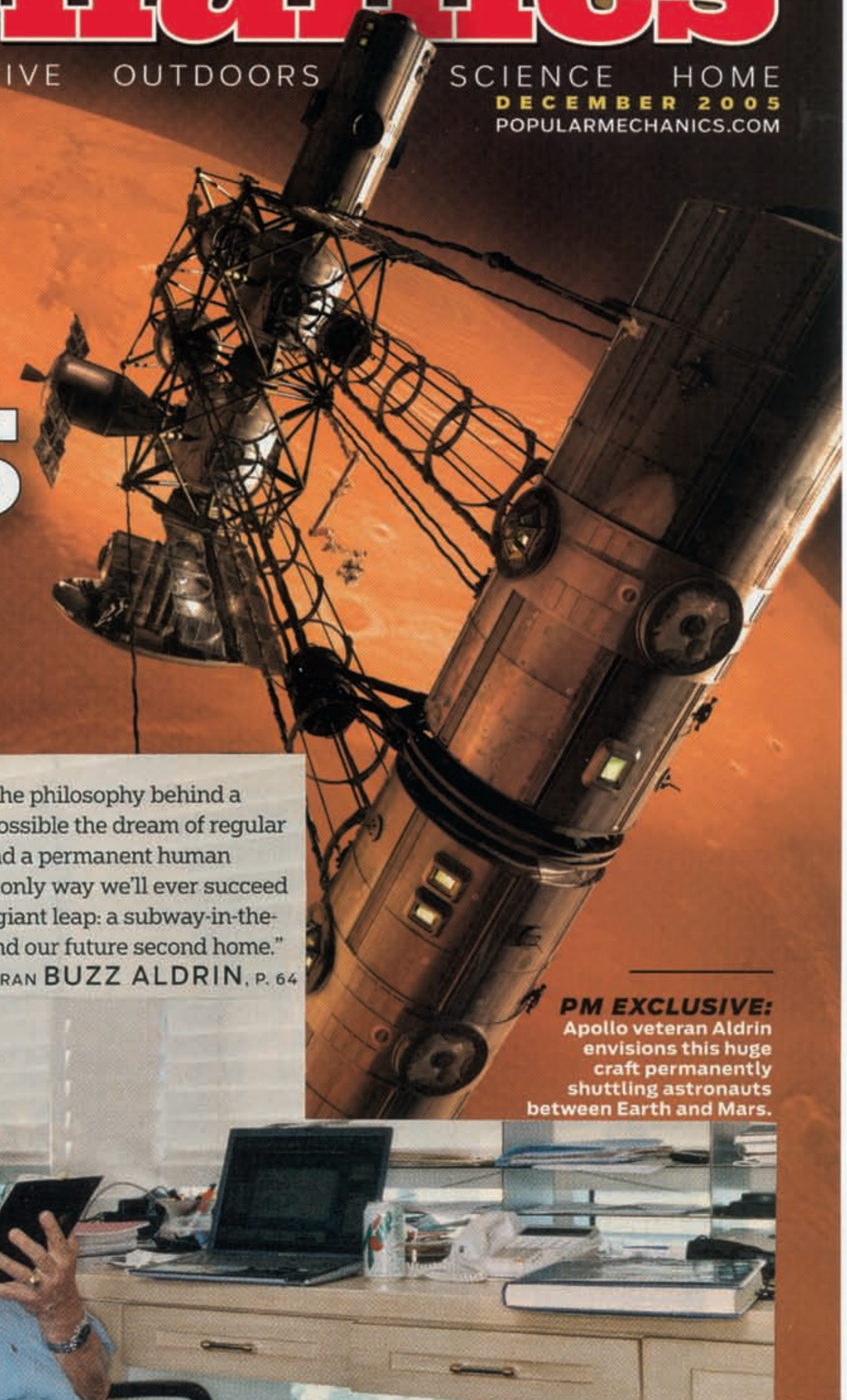


Let's Go to Mars

A STEP-BY-STEP PLAN FOR MANKIND'S NEXT GIANT LEAP

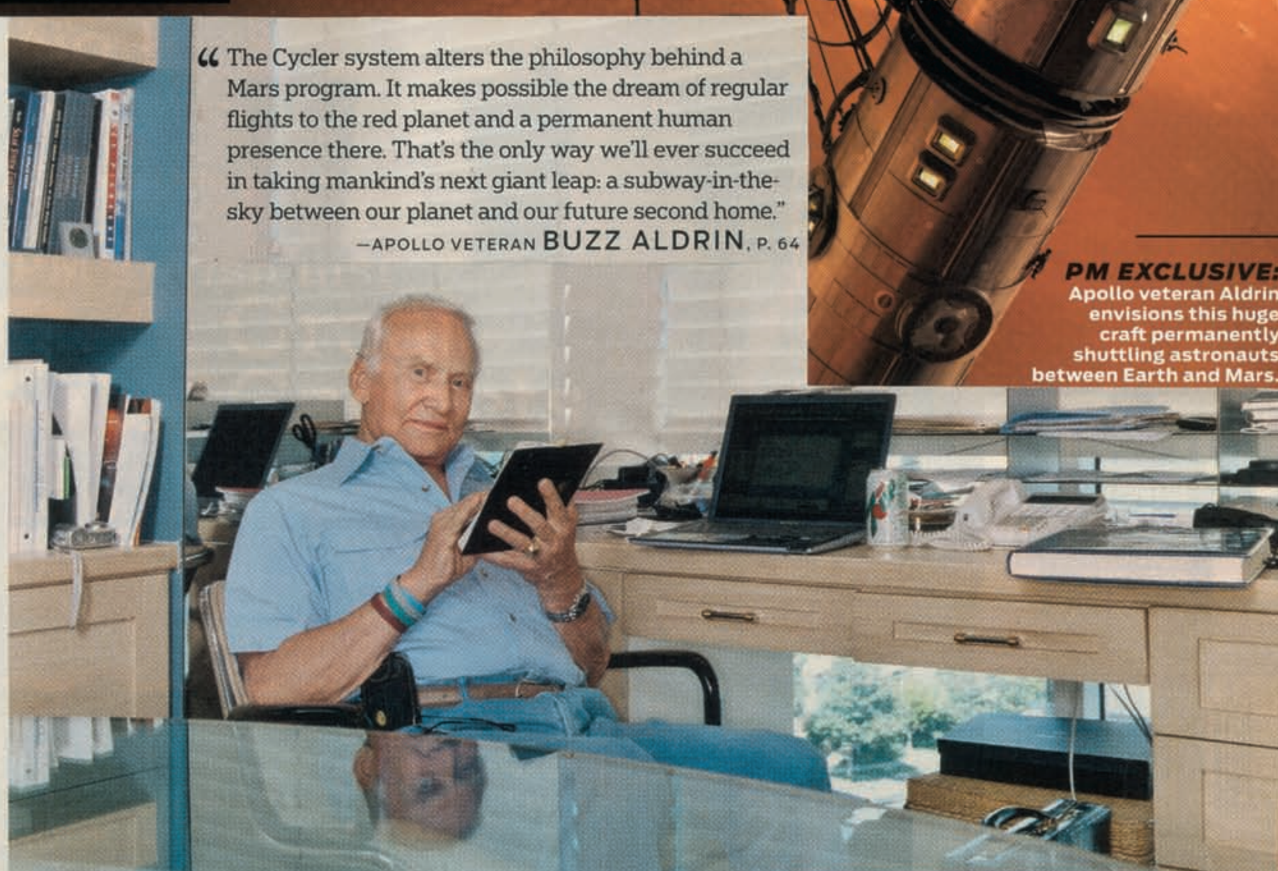
BY BUZZ ALDRIN

[redacted]

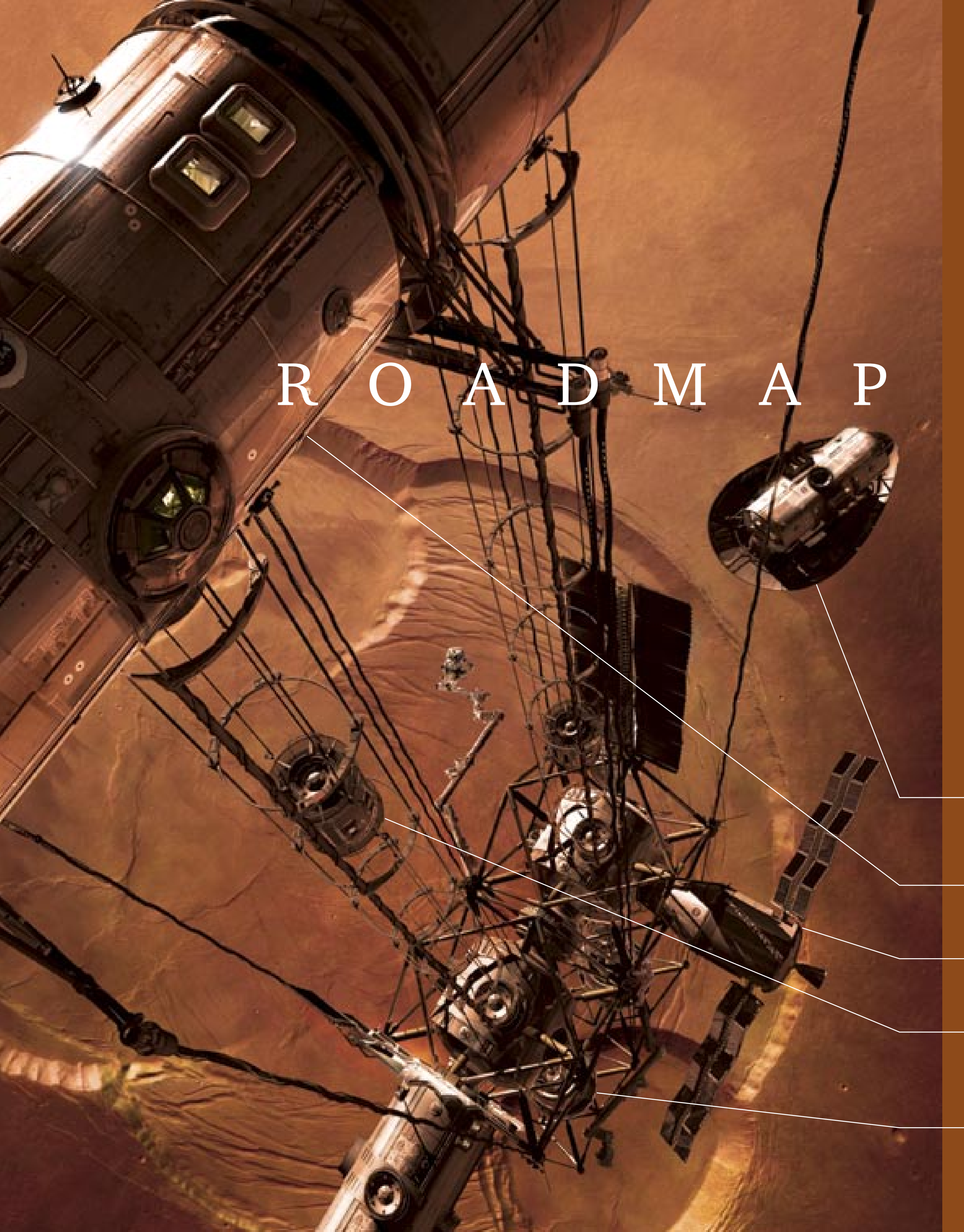
"The Cycler system alters the philosophy behind a Mars program. It makes possible the dream of regular flights to the red planet and a permanent human presence there. That's the only way we'll ever succeed in taking mankind's next giant leap: a subway-in-the-sky between our planet and our future second home."

—APOLLO VETERAN BUZZ ALDRIN, P. 64

PM EXCLUSIVE: Apollo veteran Aldrin envisions this huge craft permanently shuttling astronauts between Earth and Mars.



ROADMAP TO MARS



SO FAR, NASA'S PLAN TO REACH THE RED PLANET HAS BEEN SHORT ON DETAIL. HERE, IN A PM EXCLUSIVE, APOLLO ASTRONAUT BUZZ ALDRIN UNVEILS HIS OWN STEP-BY-STEP PROPOSAL FOR MANKIND'S NEXT GIANT LEAP.

BY BUZZ ALDRIN

WITH DAVID NOLAND

The heart of Aldrin's plan is a craft he calls a Cycler, which other vehicles will link to in a multistage mission.

Mars lander, which docks with Cycler, transports astronauts to the planet's surface.

Habitat module in Cycler holds eight crew members and supplies for the five-month journey.

CEV acts as a taxi between orbiting Cycler and Earth.

Pressurized elevators transport astronauts between CEV and habitat module.

Nuclear reactor, which generates electricity for the craft, also serves to counterbalance habitat module.

In 1961, NASA was mulling over two possible flight plans to put a man on the moon. While agency officials argued the merits of Earth Orbit Rendezvous versus Direct Ascent, John C. Houbolt, a little-known engineer at the Langley Research Center in Hampton, Va., came up with a daring and ingenious alternative: Lunar Orbit Rendezvous. LOR, which would require two spacecraft to link up a quarter-million miles from Earth, initially struck many people—me included—as dangerously complex, even bizarre. But Houbolt stubbornly kept pushing his plan, and the elegant logic of LOR eventually won over the skeptics. On July 20, 1969, thanks to Houbolt's persistence, Neil Armstrong and I walked on the moon.

More than three decades later, as NASA

ILLUSTRATIONS BY JEREMY COOK

PORTRAIT BY MICHAEL KELLEY

debates how to send humans to Mars, it's time once again to invoke the outside-the-box spirit of John Houbolt. NASA's latest thinking for a manned Mars mission is basically the Apollo program writ large: a massive disposable spacecraft that must be boosted from Earth to interplanetary velocity, and then slowed back down to alight on Mars. This flight plan has a huge energy requirement that translates directly into size, complexity and cost. Because each mission would be so extremely expensive, it's all too likely that such a program will lead to the kind of short-term "footprints and flagpoles" thinking that eventually killed Apollo.

We can do better this time. My blueprint for manned travel to Mars, based on reusable spacecraft that continuously cycle between Earth and Mars in permanent orbits, requires much less energy over the long term. Once in place, a system of cycling spacecraft, with its dependable schedule and low sustaining cost, would open the door for routine travel to Mars and a permanent human presence on the red planet. Its long-term economic advantages make it less susceptible to cancellation by congressional or presidential whim. In effect, this system would go a long way toward politician-proofing the Mars program.

FORWARD MOTION

The key advantage of a permanently orbiting spacecraft, or Cycler, is that it must be accelerated only once. After its initial boost into a solar orbit swinging by both Mars and Earth, the Cycler coasts along through space on its own momentum, with only occasional nudges of thrust needed to stay on track. This dramatically reduces the total energy required for a Mars mission. Because conventional chemical rockets are so thirsty—the mass of the *Apollo 11* craft that carried us to the moon was more than 90 percent fuel on takeoff—every pound saved pays a huge dividend in the form of less propellant and smaller, cheaper boosters.

Once established in orbit with the long-term human survival systems, radiation shield and artificial gravity mechanism necessary for a lengthy space journey, the Cycler swings by Earth and Mars on a predictable schedule. Astronauts piloting "taxi" spacecraft, such as NASA's planned Crew Exploration Vehicle (CEV), rendezvous and dock with the Cycler as it passes Earth, using only the propellant necessary to accelerate the smaller craft. As the Cycler swings by Mars, the taxi casts off and brakes into Mars orbit, like a commuter stepping off a train. The Cycler, meanwhile, speeds on beyond Mars and eventually loops back toward Earth, ready for another passenger pickup.

The idea of a Mars-Earth Cycler has been around since the 1960s. In one early scenario, space habitats called CASTLEs circled the sun in eccentric orbits that passed by both Earth and Mars. However, a Cycler using those orbits would take as long as 7½ years to complete a round trip between the two planets, and the planetary encounters would be irregular. A reasonable Mars mission schedule would have required up to six such Cyclers in staggered orbits.

It seemed to me there must be a more efficient way. Using techniques of orbital mechanics I'd developed at MIT during my Ph.D. studies, as well as firsthand insight gained by my flights on *Gemini 12* and *Apollo 11,* I calculated that the time could be significantly reduced by using gravity assist from Earth to slingshot the Cycler into a better orbit.

"Gravity assist" is a well-proven technique for interplanetary flight, routinely used on unmanned probes like Voyagers 1 and 2, Cassini-Huygens and Galileo. If a spacecraft flies close enough to a planet, its orbit will be bent by the planet's gravitational field. The process can be likened to a ball (the spacecraft) bouncing off a wall (the planet). If the wall is moving toward the ball, the rebound speed will be higher than the speed prior to impact. Similarly, if the wall is angled, the ball will change direction. In either case, a great deal of energy can be added to the spacecraft with no expenditure of propellant.

By taking advantage of gravity assist from Earth, and to a lesser extent from Mars, I was able to plot a Cycler orbit with a round-trip period of just 26 months. The Cycler would take only five months to reach Mars, comparable to the fastest transit times that NASA is now considering.

LONG-RANGE PLAN

Decades of planning and development will set the stage for manned Mars missions, resulting in a permanent interplanetary transportation system in 2036.

- **2008** — Unmanned missions start to survey the moon and to search for frozen water at the lunar poles
- **2012** — Astronauts make first manned flight of the Crew Exploration Vehicle (CEV)
- **2015** — Test flights begin for the lunar lander
- **2017** — Building materials and equipment are delivered to the moon to set up a permanent base
- **2018** — Astronauts return to the moon
- **2022** — A factory for producing propellants for future Mars missions is completed at the lunar base

FIVE-MONTH JOURNEY

Once the infrastructure is in place, the journey from Earth to Mars will take five months to complete, and involve a wide range of vehicles.

CEV with eight-man crew is launched into low Earth orbit (1). After docking with Mars lander and propulsion module (2), previously launched from Earth, CEV burns into highly elliptical "marshalling" orbit that carries it halfway to the moon (3). There, its tanks are topped off with liquid oxygen and hydrogen fuel delivered from the moon.

A permanent moon base (4)—established by numerous flights of lunar lander (5) and unmanned freighter craft—manufactures fuel from lunar ice. After a 7-minute Earth-departure burn, CEV/lander separates from propulsion module (6) and 10 days later docks with passing Cycler craft a million miles from Earth (next page).

A downside of the gravity-assisted Cycler concept, however, is that the vehicle flies by Mars at quite a high speed, up to 27,000 mph. This velocity is not a showstopper on the outbound leg, where the CEV taxi craft would aerobrake, relying on the friction of the Martian atmosphere to slow down without using any propellant. But departing Mars for the leg back to Earth, the craft would need a large amount of propellant to catch up with the speeding Cycler.

To circumvent this problem, I envision a hybrid craft called a Semi-Cycler for the return leg. Like the Cycler, the Semi-Cycler would shuttle between Earth and Mars in a gravity-assisted orbit. But it would use aerobraking in the Martian atmosphere to slow down, interrupt its cycle and loiter for four months in a wide, lazy orbit around Mars, waiting to pick up the next Earthbound taxi. With a flyby velocity as low as 5000 mph, the Semi-Cycler would be an easy target for a low-propellant taxi rendezvous. Once it discharged the spacecraft to aerobrake into the Earth's atmosphere, the Semi-Cycler would be slingshot on a circuitous 14-month route back to Mars for another run.

One drawback of the Semi-Cycler is its need for propellant to accelerate out of Martian orbit back toward Earth. But compared to a direct flight in a conventional rocket, the overall savings are still substantial. A second drawback is a longer transit time back to Earth, about eight months. But with the help of top engineers at NASA's Jet Propulsion Laboratory, Purdue University and the University of Texas, I am continuing to refine Semi-Cycler orbits to achieve optimum transit times, orbital periods and flyby velocities.

TECH SUPPORT

The Cycler itself is only the capstone of a long process of space development. NASA's proposal to revisit the moon using a CEV is a first step in the right direction. A second step would include exploratory flights to Mars's moon Phobos, which would serve as an early launchpad to the planet's surface. Creating a sustainable Mars transportation system, though, would require a huge support infrastructure.

A permanent base on the moon would use lunar ice to produce liquid oxygen and hydrogen fuel for the taxi's sprint to catch the Cycler. NASA's Clementine and Lunar Prospector missions in the 1990s discovered tantalizing hints that ice might exist deep inside craters near the lunar poles.

Liquid oxygen and methane fuel for the outbound taxis, Semi-Cycler and a Mars lander/ascender would be manufactured at a permanent base on Mars. The propellant plant would combine a feedstock of liquid hydrogen with carbon dioxide from the Martian atmosphere. If frozen water can be mined from under the poles, where recent Mars rover missions have detected it, hydrogen could also be produced.

A fleet of unmanned freighters would resupply the Cyclers and surface bases on Mars and the moon. Because they can be launched years in advance, instead of chemical rockets the freighters could use the efficient, low-thrust ion-drive engines, too slow for manned travel, that were tested on NASA's Deep Space 1 probe in 1998.

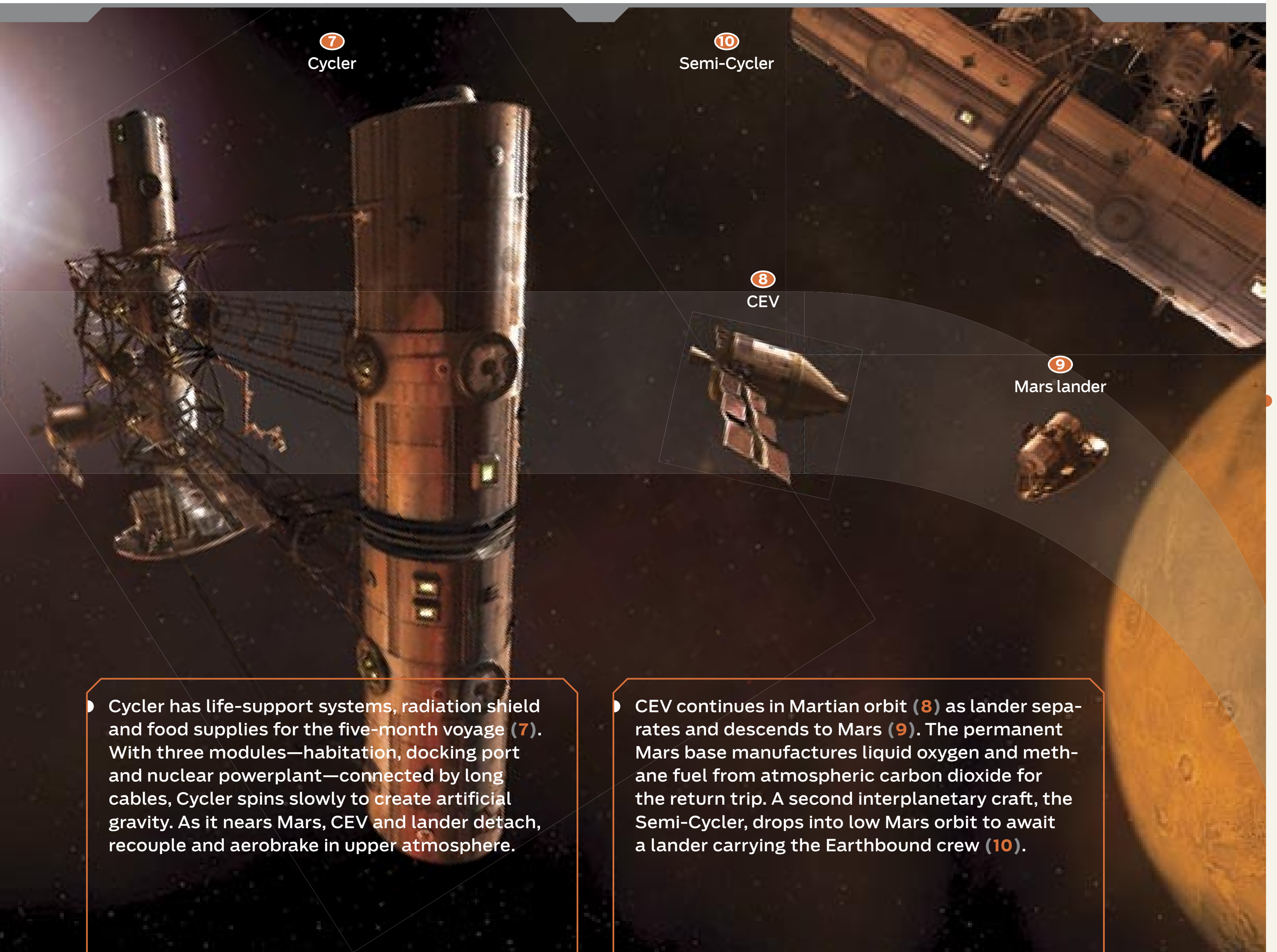
OUTBOUND JOURNEY

How would the Mars Cycler System work on a practical level? Fast-forward to the year 2040, and climb aboard for a five-year hitch in the Red Planet Corps.

You and your fellow astronauts (I envision a crew of about eight) launch from Earth in a CEV-type taxi spacecraft fueled by a high-performance hydrogen booster. While in low Earth orbit, your CEV docks with a Mars lander and a propulsion module previously launched from Earth. Linked up in this Apollo-style triple unit, you burn into a highly elliptical six-day "marshalling" orbit around the Earth that takes you roughly halfway out to the moon. There, you join up with a resupply ship carrying a load of liquid oxygen and hydrogen fuel manufactured on the moon. You top off the tanks of your propulsion module so that you can catch up with the Cycler, which is now fast approaching Earth.

The Trans-Mars Injection burn lasts about 7 minutes at an acceleration of about 2 g's. If you've done it right, you rendezvous with the Cycler about 10 days later, a million miles out from Earth. The CEV and Mars lander separate

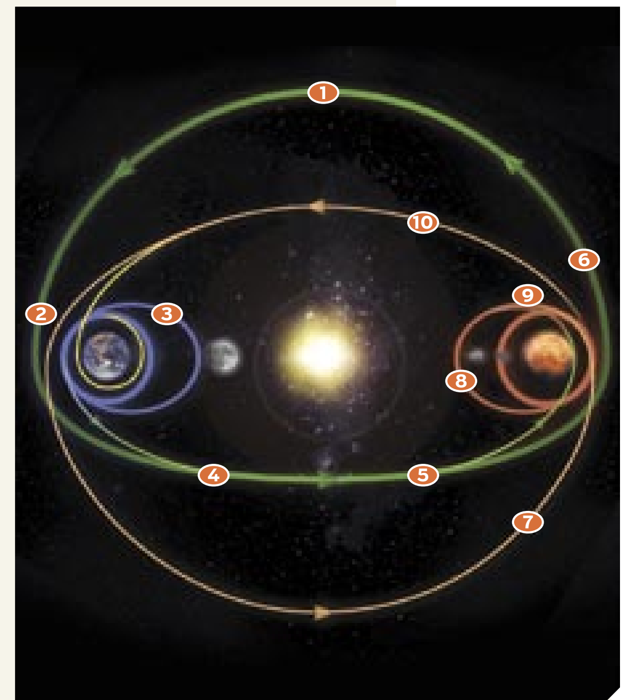
2028	2030	2032	2034	2036	2038
Unmanned flight to the surface of Mars transports components for propellant manufacturing plant	Exploratory mission is made to Mars's moon Phobos using lunar lander	Astronauts return to Phobos and, using Mars lander, descend to planet's surface for a 10-day stay	Semi-Cycler assembled in Earth orbit is accelerated into Earth-Mars orbit	Launch of Cycler into orbit and manned mission results in first 44-month stay at Mars base	Next mission catches Cycler as it once again nears Earth, initiating routine missions at 26-month intervals



Cycler has life-support systems, radiation shield and food supplies for the five-month voyage (7). With three modules—habitation, docking port and nuclear powerplant—connected by long cables, Cycler spins slowly to create artificial gravity. As it nears Mars, CEV and lander detach, recouple and aerobrake in upper atmosphere.

CEV continues in Martian orbit (8) as lander separates and descends to Mars (9). The permanent Mars base manufactures liquid oxygen and methane fuel from atmospheric carbon dioxide for the return trip. A second interplanetary craft, the Semi-Cycler, drops into low Mars orbit to await a lander carrying the Earthbound crew (10).

THE ORBITS



The Cycler's eccentric orbit carries it close by Earth every 26 months (1). Earth's gravity adds energy to the craft, slingshotting it into a five-month trajectory to Mars (2). The CEV accelerates out of its six-day "marshalling" orbit around Earth (3) to rendezvous with the Cycler (4). As the spacecraft approaches Mars, astronauts detach the CEV from the Cycler (5), which then slingshots back to Earth (6). It arrives 21 months later. The Semi-Cycler takes a circuitous 14-month route from Earth (7) and aerobrakes into a slow four-month orbit around Mars (8)—making it an easy target for the departing CEV (9). The Semi-Cycler then accelerates out of Martian orbit for the eight-month return trip (10).

from each other and dock at the hub of the Cycler (see illustration, page 64), which is spinning lazily to simulate Mars's gravity—38 percent that of Earth's. You transfer from the CEV into the habitation module, which is stocked with food, water, a radiation shield and all the necessities for a long-term journey. Here's your chance to finish *War and Peace;* there's not much to do for the next five months.

As you approach Mars, it's back into the CEV for the descent to Mars orbit. Wave goodbye to the Cycler and, with lander still attached, enter the Martian atmosphere for a few minutes of aerobraking before you skip back out into a low orbit. Here, you transfer into the lander—just like Neil Armstrong and I did on *Apollo 11*—undock from your faithful CEV and fire the lander's retrorockets for the descent to the surface. Using aerobraking, a parachute and precision rocket braking, you touch down at the main base.

Expect a champagne welcome from the crew that's still there from the previous mission, which landed 26 months earlier. They're already looking forward to using your Mars lander/ascender to head for home 18 months from now. You, however, have to wait substantially longer than that for your own rotation back to Earth.

RETURN TRIP

For the next 44 months, you explore the Martian surface, monitor a number of research projects and manage the all-important fuel-making plant. In Month 18, you send off your compatriots. Month 26 brings the arrival of the next crew and the lander/ascender you'll be using to start your eventual journey home. You then launch a refueling rocket to top off the tanks of the CEV the arriving crew left in orbit. Around Month 38, the Semi-Cycler arrives and aerobrakes into its four-month Mars orbit; you might see the bright streak as it hurtles through the upper atmosphere. As departure time draws near, the Semi-Cycler drops down into low orbit to link up with the still-orbiting CEV. You send up an unmanned rocket with fuel for the Semi-Cycler.

When it's time to go, your crew fuels up the lander/ascender and lifts off into Martian orbit to rendezvous and dock with the Semi-Cycler, now joined with the CEV. After a modest return-to-Earth burn, your Semi-Cycler departs Mars orbit for the eight-month trip home.

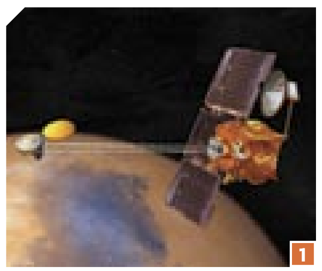
Once on the proper trajectory, you float in zero-g; the Semi-Cycler doesn't spin. I believe that artificial gravity won't be necessary on the homebound leg because the effects of long-term weightlessness (see "The Challenges of Interplanetary Travel," above) aren't as problematic upon returning to Earth's full gravity. Restorative exercises, in fact, will provide a fine opportunity to reflect upon your epochal journey.

As Earth closes in, the CEV detaches from the Semi-Cycler and aerobrakes into the Earth's atmosphere. The recovery chute deploys as you descend to a final touchdown, either into the ocean next to a waiting recovery ship or on land. The Semi-Cycler, meanwhile, whizzes on by Earth and gets slingshot back onto its return trajectory.

LOOKING AHEAD

The Cycler system alters not only the economics of a Mars program, but also the philosophy behind it. It makes possible the dream of regular flights to Mars and a permanent human presence there. Instead of a wasteful, short-term, "let's just get there as soon as possible" approach, the Cycler sets the stage for long-term thinking, planning and commitment. That's the only way we'll ever succeed in taking mankind's next giant leap: a subway-in-the-sky between our planet and our future second home. **PM**

MARS EXPLORATION ALREADY UNDER WAY



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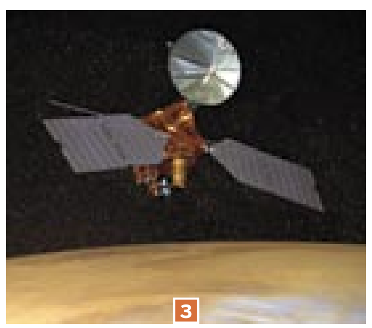

3

4

IN ORBIT: The Mars Global Surveyor arrived in orbit in 1997, and has since mapped the entire surface of the planet. Four years ago it was joined by 2001 Mars Odyssey (1), which detected huge reserves of frozen water beneath the Martian poles and tested radiation levels to prepare for future astronauts. The European Space Agency's first Mars mission, the Mars Express, entered orbit in January 2004.

ON THE SURFACE: Spirit (2) and Opportunity, the two Mars Exploration Rovers, landed on the surface in January 2004. Equipped with cameras and an array of spectrometers, the rovers set out to examine rocks and soils for signs of past activity by water. Designed to last 90 days, both vehicles are still beaming back information in late 2005.

EN ROUTE: The Mars Reconnaissance Orbiter (3), launched in August 2005, will reach Mars in March 2006. The high-resolution camera it carries will zoom in on objects only 3 ft. wide, and its high-speed communications—10 times faster than that of any previous orbiter—could help beam back data from future Mars missions.

COMING SOON: Next to touch down on Mars will be the Phoenix (4), scheduled for launch in 2007. It will land at the planet's northern pole and, using a robotic arm, dig for the frozen water detected by the Odyssey. In 2009, NASA will send another rover to Mars, twice as long and three times as heavy as the current rovers. This one will analyze terrain in more detail, vaporizing rock surfaces with a laser to search for the building blocks of life.

—Alex Hutchinson

PHOTOGRAPHS BY NASA

THE CHALLENGES OF INTERPLANETARY TRAVEL

Even with a route mapped out, getting to Mars presents extraordinary difficulties. The Cycler's artificial gravity will ease the zero-g problems of muscle atrophy, bone loss and heart arrhythmia, but space travel is still an ordeal for the body. Another obstacle: how to propel payloads to support a Mars base. A Cycler system reduces the amount of propellant required, but improvements to propulsion may make it even more practical. *—A.H.*

RADIATION: Cosmic radiation and deadly solar flares could be the greatest risk to Mars-bound travelers. The concrete blocks used for shielding in nuclear plants are too heavy to bring along, but certain plastics, along with plain water, can block some particles. A more futuristic approach would be to surround the spaceship with a magnetic shield, which would deflect radiation like a miniature version of Earth's magnetic field.

STRESS: Cabin fever will be a problem for long-haul space travelers, possibly leading to boredom, depression and even violent disputes. Disrupted sleep cycles make it worse: With no 24-hour light cycle, astronauts sleep an average of 6 hours a day. A successful crew will need to be fully alert and cooperative, so scientists are researching ways to fool circadian rhythms with artificial sunlight and drugs. Sensors able to read facial expressions might predict when an astronaut is in a poor emotional state. And, of course, potential astronauts will be rigorously screened to make sure they are stable from the start.

INFECTIONS: Other potential dangers in a tightly sealed spaceship include drug-resistant microbes and chemical leaks, like the antifreeze seeping from an air conditioner that caused breathing problems for cosmonauts aboard the *Mir* space station in 1997. Scientists at Boston University are developing a biosensor that will recognize the surface shape of harmful microbes, allowing the air quality in the crew's quarters to be continuously monitored with extreme sensitivity.

Aldrin's plan calls for both chemical rockets (for the CEV) and ion drives (for unmanned freighters); the Cycler simply coasts along in high-speed orbit. The downside of high-thrust chemical rockets is that they burn a lot of propellant. The ion drive (below) is extremely efficient, but takes a long time to pick up speed. To get there faster, engineers can squeeze 100 times more power from an ion drive by using nuclear fission. Or they can skip the ion drive and use nuclear thermal propulsion, in which a nuclear reaction heats a gas and expels it from the rocket. Both methods have potential, but budget cuts have put the future of NASA's nuclear research program, Prometheus, in doubt.

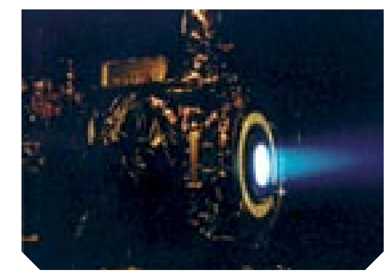

ILLUSTRATION BY TRANSLUSZENT.DE (MAN)