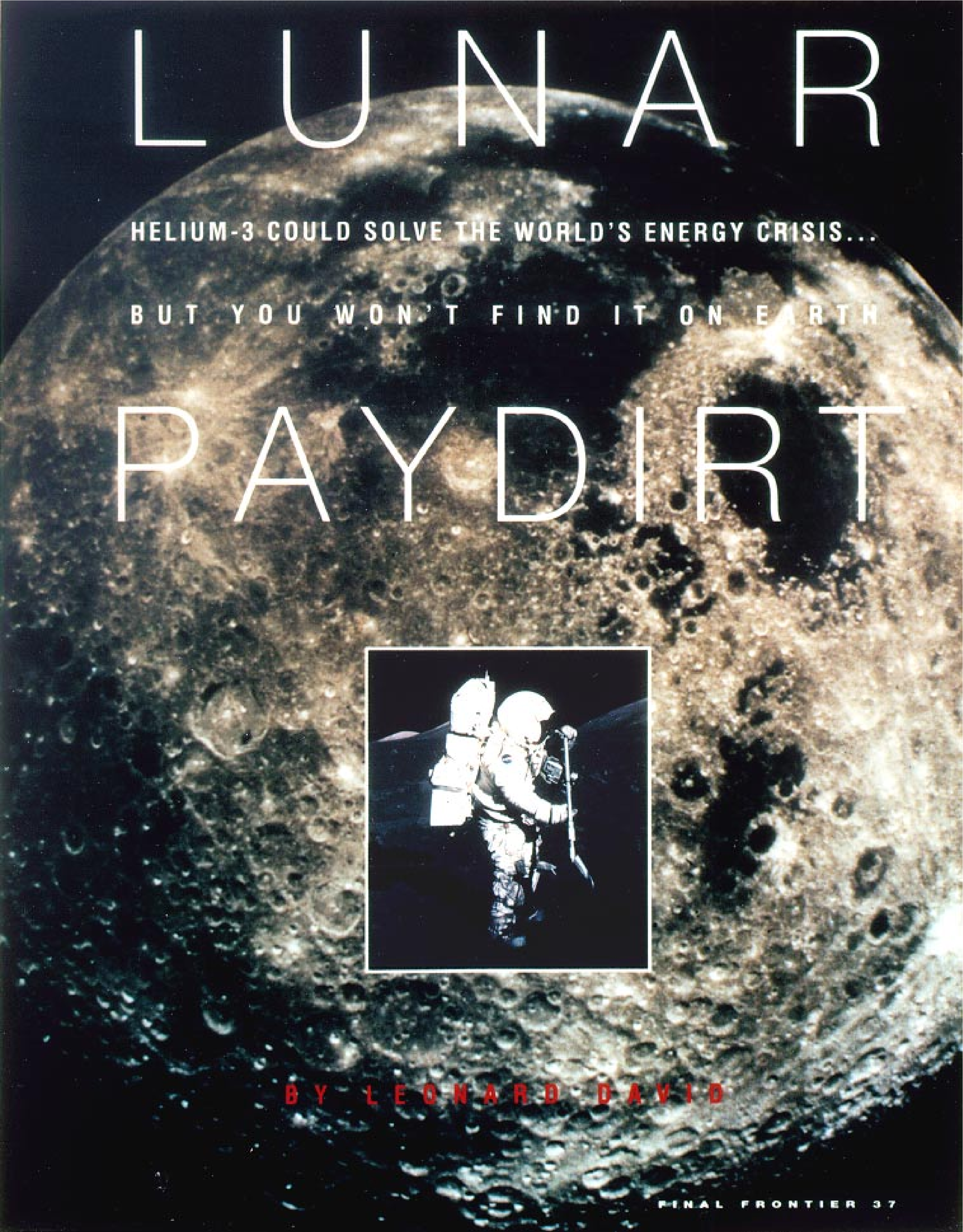
LUNAR

HELIUM-3 COULD SOLVE THE WORLD'S ENERGY CRISIS...

BUT YOU WON'T FIND IT ON EARTH

PAYDIRT



BY LEONARD DAVID

Apollo Moonwalkers, in a very real sense, were the first prospectors of another world. They chipped...they scooped...they drilled and bagged a preliminary assay of Moon rock and regolith—the fine-grained powdery layer on the lunar surface. Over 840 pounds of Moon samples were hauled back to Earth.

Now, after more than 20 years of studying those samples, a growing choir of engineers and scientists have concluded that there's much more to the lunar surface than meets the eye. Forget all that talk about "magnificent desolation," they say; the Moon has the potential of becoming prime real estate. The reason? Researchers have concluded that the lunar surface holds vast deposits of Helium-3, a potentially cheap and clean source of energy that is creating the space age equivalent of gold rush fever.

"We need to find an adequate, safe, clean and economical source of energy for the 21st century," says Gerald Kulcinski, professor of nuclear engineering at the University of Wisconsin-Madison and director of the Fusion Technology Institute in Madison. "We're not worried about the next five to ten years; we're obviously going to burn fossil fuels and stay with our present situation. But in the 21st century, that's where the real crunch comes, when we run out of liquid and gaseous fuels and find out whether or not we'll be able to handle all the pollution and surface disruption of coal mining," Kulcinski says.

Nuclear energy in the form of fission has fallen victim to a meltdown in public confidence, courtesy of Three Mile Island and Chernobyl, says Kulcinski. On the other hand, in recent decades, nuclear fusion research—based on a fuel cycle that uses the reaction between deuterium and tritium—has moved this choice of energy closer to reality. Fusion is the same reaction that powers the Sun and the stars.

But there's a catch...and a radioactive one at that.

"Nuclear fusion has been studied for over 30 years and the reaction between deuterium and tritium is the major fuel cycle pursued around the world today," Kulcinski says. "Unfortunately, 80 percent of the energy from this reaction appears as neutrons which, in turn, induce radioactivity in the [reactor's] structural components."

In less energetic lingo, that means damage to the reactor itself and production of hazardous radioactive wastes.

Kulcinski and his colleagues argue for a second generation fusion device—a reactor that can use a more attractive thermonuclear fuel and reduce the problems associated with a deuterium-tritium reaction by a factor of 100. That fuel is Helium-3. It releases as little as one percent of its energy in the form of neutrons. Furthermore, most of the energy from a deuterium-Helium-3 reaction can be converted to electricity at efficiencies of over 80 percent.

An even more speculative fusion reactor would utilize Helium-3-Helium-3. This reaction creates no radioactive waste and no safety problems, and lasts for thousands of years.

Yet, once again, there's a catch.

Quantities of Helium-3 on Earth are meager, something on the order of a few hundred pounds. To energize the globe would require dozens of tons of Helium-3 each year. So how on Earth can you solve the problem? The answer isn't on Earth, but has been blowing in the solar wind, contends Kulcinski. It now resides on the Moon in a form Kulcinski calls "Astrofuel."

Above: A lunar sample brought back to Earth by the crew of Apollo12.

Lunar samples brought back to Earth by Apollo astronauts and Russian robotic probes show that Helium-3 has been implanted in the Moon's soil for billions of years by the caressing blast of solar wind.

According to Apollo 17 astronaut Harrison Schmitt, the six Apollo landings on the Moon have provided a first order understanding of what elements make up the lunar regolith. Fifty to sixty percent of the regolith down to depths of five to ten meters consists of particles that average less than 100 microns in size. That means it's dust, explains Schmitt, the only geologist to personally survey the lunar landscape.

In a natural process called "gardening," small meteorite impacts have peppered the lunar surface for eons. That has churned up and pounded the regolith, thereby turning over the soil and exposing it to solar wind bombardment.

The first lunar samples, Schmitt recalls, showed that the pulverized surface materials of the Moon partially retain volatiles carried by the plasma waves of the solar wind. One of those volatiles is Helium-3.

Volatile substances are easily boiled out of the lunar surface materials by heating the material to high temperatures. Therefore, if the regolith was heated to 700 degrees Celsius, over 85 percent of the trapped Helium-3 would be released. A large mobile Moon mining vehicle would do all the dirty work of combing the Moon's surface and distilling gases from the lunar soil. The Helium-3 would later be liquified on the Moon for hauling back to Earth.

"Although we have limited data on the variations of volatile content with depth, the drill cores we have indicate no trends toward a decrease in concentrations to depths of three meters," Schmitt notes.

Research by Schmitt and Kulcinski, as well as Layton Wittenberg of the Fusion Technology Institute, suggests that the Helium-3 in the lunar regolith is present in amounts that vary from 10 to 40 parts per billion by weight. But even those sums suggest that the total quantity of Helium-3 in that first three meters would equal about one million tons, including both mare and highland areas of the Moon.

That quantity of Helium-3, if extracted from the Moon, could yield ten times more energy than all the economically recoverable fossil fuels on Earth as defined by the U.S. Department of Energy.

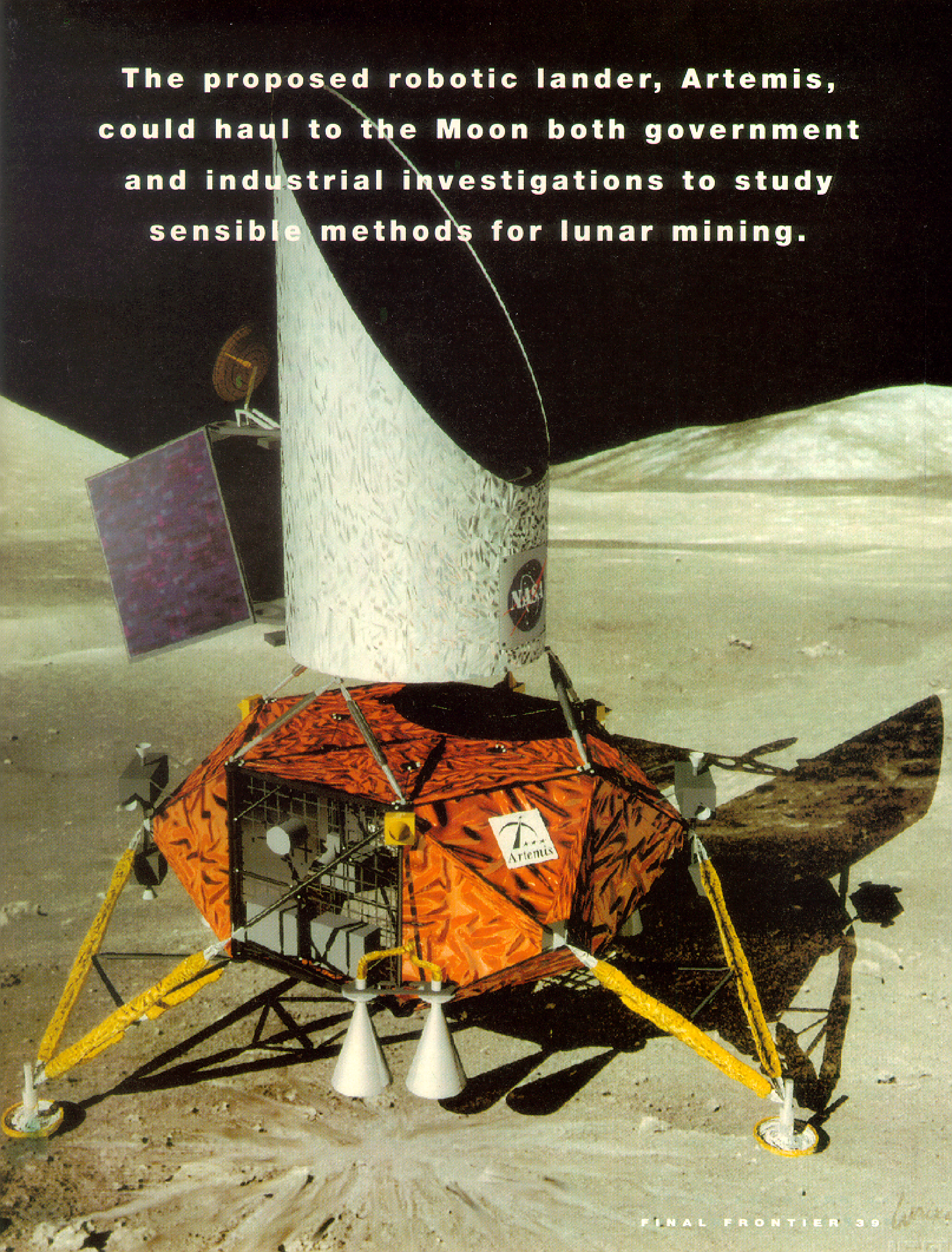
There is no argument that the scale of operations to mine the Moon for Helium-3 would indeed be large. It has been estimated that approximately 200 million tons of regolith would have to be moved for every ton of Helium-3.

"One metric ton of Helium-3 is equivalent to $3 billion worth of coal today. That's not a bad number. That is the kind of number which you can anchor a future business plan on for this type of activity," Schmitt says. But, he adds, business and financial communities want to see a return on investment (ROI) in time frames significantly less than 25 to 30 years.

"That is the showstopper, from a financial point of view," Schmitt admits. Now a space consultant living in New Mexico, the former astronaut has been busily sketching out a step-by-step Helium-

(continued on page 44)

The proposed robotic lander, Artemis, could haul to the Moon both government and industrial investigations to study sensible methods for lunar mining.



3/Moon mining business plan. "I'm trying to see if there are opportunities three to five years apart for a competitive return on investment, before you get to that big ROI in the sky," he says.

Another scientist eyeing the Moon as potential paydirt is W. David Carrier, III, director of the Lunar Geotechnical Institute in Lakeland, Florida.

"The mining operations on the Moon, even for Helium-3, are tiny compared to what we already do on Earth. It is not beyond our terrestrial experience by any means," Carrier says.

For those fearing a gobbling Pac Man mining exercise chomping away at the Moon, Carrier sees no cause for alarm, either by environmentalists or, for that matter, romantics.

"The actual mining of the surface itself would not be visible to people standing on Earth, or even looking at the Moon with a powerful telescope. We're not going to eat up the Moon. There will not be an observable change," he says. Mining an area about the size of Washington, D.C. is not projected to take place by Helium-3 advocates until several decades into the 21st century. The mines' size will depend on the depth of recoverable Helium-3, Carrier says. Prime real estate for the first Helium-3 mining ventures appears to be in the northern half of the Moon's Mare Tranquillitatis—an area of highest potential concentration or "grade" of the material.

To be economical, the number of people required to excavate the Moon has to be less than the number required for terrestrial mining, Carrier argues.

"We feel the technology either already exists, or is close to being available for a combination of robotics and telerobotics to remotely mine the Moon," Carrier says. "That would keep the numbers down to no more than 10 to 20 people on the Moon, perhaps up to 50 individuals for a full-scale mine that would supply the U.S., or perhaps the whole world's electrical needs," he says.

Also feeling bullish about the prospects for Helium-3 is NASA chief Daniel Goldin. Speaking July 1 at a Senate space subcommittee hearing, Goldin told lawmakers: "It's not inconceivable that 50 years from now we may be able to mine Helium-3. And if at the same time, in parallel, we work on a yet undefined controlled thermonuclear reaction using Helium-3...40,000 pounds of Helium-3 could provide enough energy for the United States of America for one year," Goldin told the lawmakers.

Meanwhile, at the Johnson Space Center in Houston, NASA's Mike Duke, the deputy for science in the New Initiatives Office, believes that the jury is still out on Helium-3.

"I'm not personally willing to sign on to Helium-3 as the way to save the world, but it's one of those things that you want to hold open as a possibility," Duke says. "It is yet to be demonstrated to the satisfaction of numbers of folks that you can actually get more energy out of the process than you put in, in order to extract the Helium-3 and bring it to the point where it can be used," he explains.

Duke contends that sets of experiments should be carried out on the Moon to demonstrate lunar processing concepts, like the Helium-3 proposal. "It really depends on getting data...doing experiments that can really demonstrate how difficult or how easy it is to extract Helium-3 from lunar soil," Duke says. One way to conduct those tests is via a robotic craft, called Artemis, now under study by NASA. This soft-lander could haul to the Moon both government and industrial investigations to study sensible methods for lunar mining.

The prospects for Astrofuel mining also offer some enticing benefits, former astronaut Schmitt emphasizes. Helium-3 processing on the Moon churns out a byproduct bonanza of hydrogen, water (a source of oxygen), nitrogen oxides, and carbon dioxides. Kulcinski estimates that "the byproducts from 20 tons of Helium-3 would support a city of over 100,000 people on the Moon."

These resources are useful not only for a self-sustaining lunar settlement, but could initially foster the establishment of Mars outposts as well, Schmitt and Kulcinski say. That strategy, therefore, might transform the Moon into the Hudson Bay Company of space—a convenient stopover on the frontier to stock up on food and water enroute to other destinations. Those other destinations could be the outer planets.

"There are vast, vast quantities of Helium-3—many orders of magnitude more than on the Moon—in the atmospheres of Jupiter and Saturn," suggests Carrier of the Lunar Geotechnical Institute. "The Moon will kick-start us. It will provide sustenance and succor, until we're ready and able to go on to where the really big prizes are," he adds.

That forward-looking view is shared by the Harris Corporation's Bill Braselton, vice president for business development at the firm's government aerospace division in Melbourne, Florida. "We have to fix the space program. We have to motivate the public and show them our space program has a very tangible purpose. Nobody tells them the reason for returning to the Moon. It's not to do more research or have astronauts dance in the dust," Braselton says.

The Harris Corporation executive has plotted a 100-year plan. Unfolding in separate epochs, the visionary script is replete with interstellar-bound crews headed towards Alpha Centauri, propelled there by nothing less than Helium-3 nuclear fusion powered matter/antimatter annihilation engines.

A bottom line, no-nonsense rationale for focusing on a long-term vision now, says Braselton, is the depletion of economically recoverable fossil fuels in about 50 years. "We need an alternative. The parents must begin to realize, your kids are going to run out of gas," he explains.

"There is $3 quadrillion worth of Helium-3 sitting on the Moon," Braselton estimates. "And that's at today's oil price, not tomorrow's. As we run out of oil, the price will go up. Unfortunately, there is very little Helium-3 naturally occurring on Earth, so we have to go to the Moon. But big deal...so what...let's go get it!" ■

Leonard David wrote about space spinoff technology in our July/August issue.